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U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	ki'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps=2.22 $\times 10^{12}$ dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces= 2.205×10^{-3} pounds
Hz	herts	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches=3.28 feet
m^3	cubic meter(s)	
mCi/ml^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/ml^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
r/min	revolutions per minute	
s	second	
yr	year	

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RADIATION DATA AND REPORTS

Volume 15, Number 6, June 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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Environmental Protection Agency
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U.S. ENVIRONMENTAL PROTECTION AGENCY

Russell E. Train, Administrator

Reports

Calculations of Dose, Population Dose and Health Effects Due To Boiling Water Nuclear Power Reactor Radionuclide Emissions In The United States During 1971 [1]

J. A. Martin, Jr. and C. B. Nelson [2]

Atmospheric emissions of radionuclides during 1971 reported by operators of 10 boiling water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A recently developed computer program (AIREM) was used to perform the calculations. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 80 kilometers. In 1971, 3.2 million curies of radioactivity were released to the atmosphere from 10 reactors. The resulting whole body population dose was calculated to be 900 person-rem. The health effects associated with this population dose were calculated to be small fractions of those induced by natural background radiation.

The Office of Radiation Programs (ORP) is analyzing reported airborne emissions of radionuclides from operating boiling water nuclear power reactors to calculate doses [3] to populations within 80 km (50 miles) of the emission points. This report summarizes calculated doses due to radionuclides emitted by such facilities during 1971. Doses were calculated using the AIREM (*1*) computer code recently developed for this purpose by the Surveillance Branch, ORP. This code diffuses the radionuclides according to a standard long-term, sector-averaged equation (*2*) and includes ground and inversion lid reflections, radionuclide decay by time-of-flight, ground deposition and cloud depletion, first daughter product in-growth and decay, and contributions to dose from radionuclides in clouds at all azimuths. Whole body doses due to the gamma rays emitted within the cloud (cloud gamma doses) were calculated using a model that considers the finite extent of the cloud, all decay gamma energies, and dose buildup factors. The finite cloud model used is a modified version of R. E. Cooper's EGAD code (*3*). For doses other than cloud gamma doses, dose rate conversion factors (rem/year per Ci/m^3) were obtained using techniques suggested in references *4* and *5*. Gamma and beta intensity data were obtained from reference *6*. Plume rise was calculated according to the methods of Briggs (*7*). The geometry of the AIREM code is as illustrated in figure 1. Ground level doses are calculated for each sector-segment. The populations within sector-segments are assumed to exist full time at the points (denoted by X's) where doses are calculated. Incremental population dose is the product of the population in a sector-segment and the dose in that sector-segment. Total population dose is the sum of all the incremental population doses. Average dose to the population is the total population dose divided by the total population. Health effects were calculated using a risk factor of 7×10^{-4} health effects per person-rem (*4*).

A large body of data was accumulated and used in the calculations. Stack dimensions and exit gas parameters (e.g., flow rate, tempera-

[1] This article is based on a paper that was presented at the International Atomic Energy Agency/World Meteorological Organization Symposium on the Physical Behavior of Radionuclides Released to the Atmosphere, Vienna, Austria (November 1973).

[2] Field Operations Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460.

[3] Corresponding to common practice, dose = dose equivalent in this report.

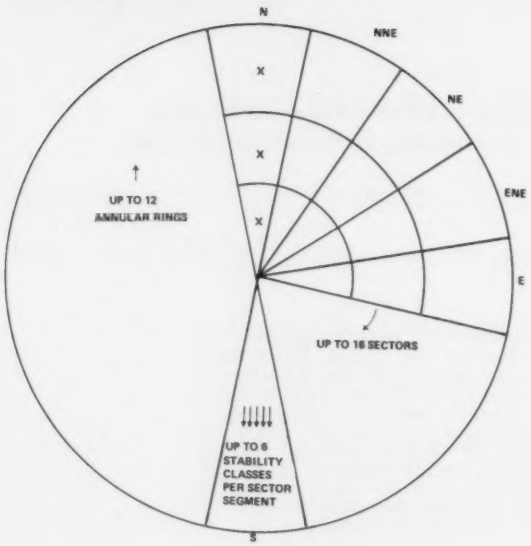

Figure 1. Geometry of AIREM

ture) were obtained from facility operators, as were plot plans of the facilities. Source terms (activity of each radionuclide released) were obtained from published AEC data (*8*) or from the AEC directly when the published data did not detail the release by radionuclide. Wind frequency and wind speed distributions used in the calculations were facility-provided annual averages; these were all obtained from onsite meteorological instrumentation. Cloud diffusion parameters used were those suggested by the EPA Office of Air Programs (*2*). Annual average height of the mixing layer was obtained from reference *9*.

The 1970 census data were used to determine population distributions. Where deposition was calculated (i.e., for the iodines and particulate daughter products), a deposition velocity of 1 centimeter per second was assumed. Most facility-provided data have been reported in either their safety analysis or environmental reports; however, in several cases, the facility provided as yet unpublished data through the EPA Regional Radiation Representatives.

Code comparisons

A complete description of the calculations performed for the subject facilities is beyond the scope of this report; such will appear in the code program manual presently being written (*1*). Two examples are presented here, however, to illustrate some significant comparisons to common experience.

Finite cloud vs. semi-infinite cloud doses

The assumption of a semi-infinite cloud has often been used (*4,5*) to calculate cloud gamma dose. The differences between doses calculated using AIREM with the modified EGAD finite cloud model and doses calculated using the semi-infinite cloud model are displayed in figure 2. The same sector-averaged diffusion equation (*2*) was used in both cases. As expected, the difference is small at large distances from the release point since by then the cloud has expanded considerably and the semi-infinite cloud assumption is valid. At intermediate ranges, the semi-infinite cloud assumption overestimates the dose since it assumes that the concentration (Ci/m^3) everywhere is identical to the ground level concentration, whereas, the concentration

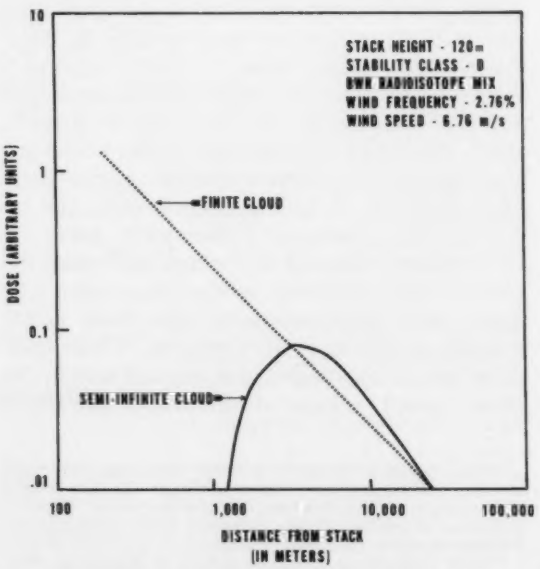

Figure 2. Comparison of external gamma whole-body dose calculated using finite and semi-infinite cloud dose model

actually varies with height. At close distances the semi-infinite cloud assumption results in very low underestimates of doses since the ground level concentration of radionuclides can be orders of magnitude less than the concentration overhead.

Sector-averaged vs. single plume dose calculations

Cloud gamma doses can be calculated using a single plume model, but this approach is not appropriate for long-term average calculations (*10*). AIREM is based on sector-averaged diffusion to be compatible with wind rose data. Figure 3 presents an example of differences in the results obtained using the two diffusion models.

At large ranges, the sector-averaged diffusion equation (assuming a 22.5° sector) leads to calculated doses that are lower than for the single plume. In the sector-averaged model, the activity is uniformly distributed across the sector at all heights, whereas, the single plume model restricts the crosswind horizontal spread of the plume. Thus, the single plume model results in higher centerline doses at large distances from the release point.

At close ranges, AIREM assumes that equal clouds exist in adjacent sectors (figure 4). This results in a higher calculated dose than the single plume model.

Data

Plume rise

Table 1 presents stack data and results of plume rise calculations. Up to 100 meters of plume rise was added to the stack heights of the various BWR's to obtain the effective stack heights (H_{eff}). Dose integral tables were prepared for release heights of 75, 100, 120, 150,

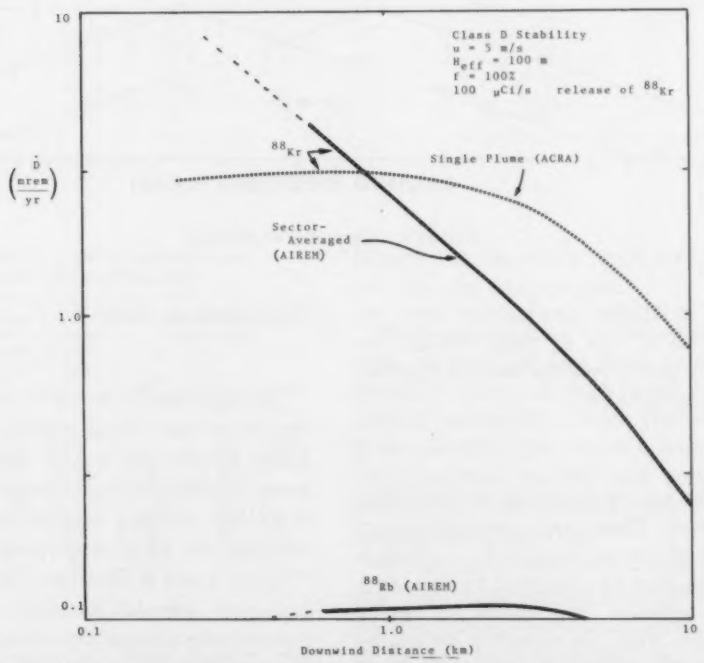

Figure 3. Comparison of cloud gamma dose rate calculated using single plume (ACRA) and sector-averaged (AIREM) diffusion models

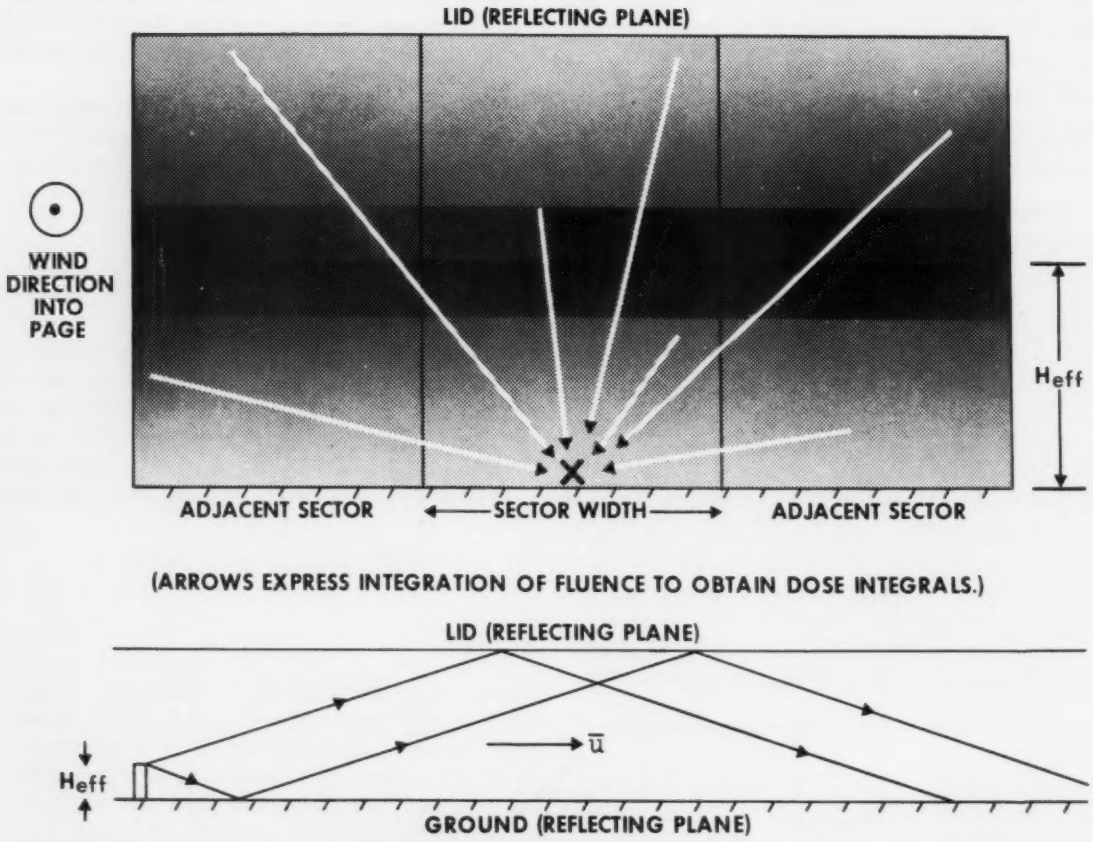

Figure 4. Geometry of AIREM

and 200 meters. AIREM calculations were restricted to the use of one of these values for H_{eff}. The effective stack heights used in the calculations are listed in table 1.

Source terms

Table 2 lists the source terms by radionuclide used in the analyses. These data are a summary of data presented in reference *8*. Although certain anomalies may be observed in this data compilation, no attempt was made to verify these source terms. Also, the reported emissions were presumed to be emitted from the stacks of the BWR's, rather than lower level vents.

Cloud gamma doses

Tables 3 and 4 present the highlights of the results of the cloud gamma dose calculations. Table 3 lists the source terms and maximum doses at the site boundaries; table 4 presents the cloud gamma population doses. All doses are for the first centimeter depth of muscle. Figures 5 and 6 illustrate the growth in population and population dose, respectively, with distance for several facilities. Table 5 illustrates the radionuclide contributions to the population dose in a few selected cases.

Table 1. Calculated plume rise for operating BWR's

Facility	Stack height	I.D.[a] (m)	W_o[b] (m/s)	Q_H[c] (10^6 cal/s)	H_{eff}[d] (m)	H_{eff} used for AIREM calculations (m)
Big Rock Point	75	1.14	12	3.2	108	100
Dresden 1	92	1.22	18	3.5	134	120
Dresden 2, 3	94	3.3	4	25	201	200
Genoa	107	1.37	21	2.1	149	150
Humboldt Bay	75	.45	16	.1	75	75
Millstone-1	115	2.14	24	5.0	168	150
Monticello	100	.36	19	.1	100	100
Nine Mile Point	107	2.6	19	13.2	162	150
Oyster Creek	110	2.5	16	7.4	166	150
Pilgrim	100	.73	19	.3	126	120
Vermont Yankee	94	2.1	18	14	174	150

[a] I.D. Exit diameter of stack.
[b] W_o—Gas exit velocity.
[c] Q_H—Thermal power of stack gases.
[d] Class D stability; 5 m/s winds; Briggs equations.

Table 2. Noble gas radionuclide emissions reported for 1971

Radionuclide	Emissions (kCi)									
	Big Rock Point	Dresden-1	Dresden-2	Dresden-3	Genoa (LaCrosse)	Humboldt Bay	Millstone-1	Monticello	Nine Mile Point	Oyster Creek
Krypton-83m	—	—	—	—	—	15.5	—	—	—	—
Krypton-85m	0.22	33.2	48.4	1.8	0.11	23.7	16.1	5.9	20.3	41.3
Krypton-85	13.9	—	—	—	—	.001	—	—	—	—
Krypton-87	28.5	90.2	84.5	2.0	.01	66.4	17.8	8.9	35.8	72.1
Krypton-88	40.9	82.9	108.3	2.3	.005	75.4	35.5	10.5	33.5	67
Krypton-89	—	—	—	—	—	.033	—	—	—	—
Xenon-133m	—	—	—	—	—	1.35	—	—	—	—
Xenon-133	33.8	54.9	115.1	5.9	.008	49.6	102.6	13.7	42.7	119
Xenon-135m	11.5	147.7	20.2	—	—	45.4	—	—	—	25.8
Xenon-135	77.1	109.3	176.4	2.9	.074	125.6	77.8	15.8	75.4	165
Xenon-137	—	—	—	—	—	.27	—	—	—	—
Xenon-138	67.1	235.6	20.5	.4	.065	108.6	2.45	2.4	22.4	25.8
Total	273	754	573	15.3	[a] 0.56	512	252	[b] 57	230	516

[a] Includes 226 Ci nitrogen-13 and 52 Ci oxygen-15.
[b] Includes 0.132 kCi argon-41.
—, not reported.

Table 3. 1971 summary, BWR emissions and calculated cloud gamma dose

Facility	Energy generated [GW(e)-yr][a]	Total emissions (kCi)	Maximum dose at site boundary[b,c]		
			Dose (mrem)	Distance (m)	Sector
Big Rock Point	0.041	273	5	668	WSW
Dresden 1	.082	754	12	1 219	SSE
Dresden 2	.30	573	2.6	1 767	S
Dresden 3	.11	15	.06	1 767	S
Genoa	.025	.56	.02	805	S
Humboldt Bay	.039	502	66	254	SE
Millstone-1	.39	252	[d] 3	492	NE
Monticello	.15	57	2.0	704	SSE
Nine Mile Point	.31	230	4.6	335	S
Oyster Creek	.40	516	13	400	NE

[a] Assumes 0.3 electrical to thermal efficiency. 1 GW(e)-yr = 10^9 watt years electric.
[b] No credit given for occupancy factor or building shielding.
[c] Dose scales approximately linearly with distance. Doses to actual individuals were factors of 2 to 3 lower.
[d] Doses at onsite Navy Lab and Desalination Plant are higher by a factor of 1.3.

Inhalation, ingestion, and direct doses from particulates and halogens

There are no direct correlations between locations of maxima for cloud gamma, inhalation, ingestion (e.g., of milk) and direct (from deposited material) doses. Indeed, doses due to these various dose modes usually peak at different locations (ranges and azimuths) about a given site. Some general results may be briefly summarized, however.

Whole body doses due to gamma rays emanating from rubidium-88 and cesium-138 deposited on the ground were calculated and were found to be less than 1 percent of the cloud gamma doses at all distances.

Table 4. 1971 populations and calculated cloud gamma population doses

Facility	Population within 80 km (millions)	Population dose within 80 km (person-rem)	Average dose per person within 80 km (mrem)
Big Rock Point	0.15	9	0.06
Dresden 1	6.1	330	.05
Dresden 2	6.1	270	.05
Dresden 3	6.1	6	.001
Genoa	[a] .122	[a] .02	<.001
Humboldt Bay	.1	61	.6
Millstone–1	2.5	75	.03
Monticello	2.6	26	.01
Nine Mile Point	1.0	13	.01
Oyster Creek	3.6	115	.03

[a] Forty km radius, population and population dose.

Table 5. Radionuclide contributions to cloud gamma population doses (person-rem) for three population distributions (1971 emissions)

Nuclide	Half life	Humboldt Bay[a]	Monticello[b]	Oyster Creek[c]
Krypton–85m	4.4 h	0.9	0.9	3.5
Krypton–87	76 min	6.3	1.9	9.8
Krypton–88	2.8 h	23.7	12.3	48.7
Rubidium–88	17.8 min	5.0	4.5	17.4
Xenon–133m	2.3 day	0		
Xenon–133	5.3 day	.9	1.3	6.6
Xenon–135m	.26 h	1.4		.2
Xenon–135	9.2 h	6.1	4.2	25.8
Xenon–138	14 min	8.9	.1	.6
Cesium–138	32 min	8.0	.3	2.6
Total		61.2	25.5	115.2

[a] Pacific site-majority of population is within 8 km (5 miles) to N and S.
[b] Inland site-major population center is 50 km (35 miles) to SSE in predominant wind direction.
[c] Atlantic site-large population centers at 80 km (50 miles) to N and W.

At distances within 2 km of a 100 m (or higher) stack, the total whole body dose due to rubidium-88 and cesium-138 is less than 1 percent of the cloud gamma dose due to all noble gases. This total includes the inhalation whole body dose and the external gamma dose due to the radionuclides deposited on the ground. However, because of continued ingrowth, these radionuclides can contribute 15 to 20 percent of the total cloud gamma population dose within 80 km.

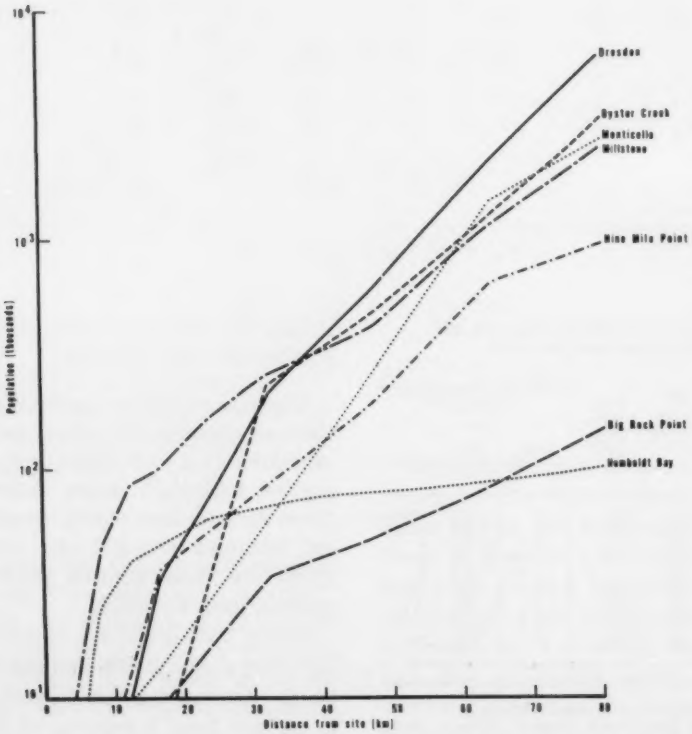

Figure 5. Growth in population with distance

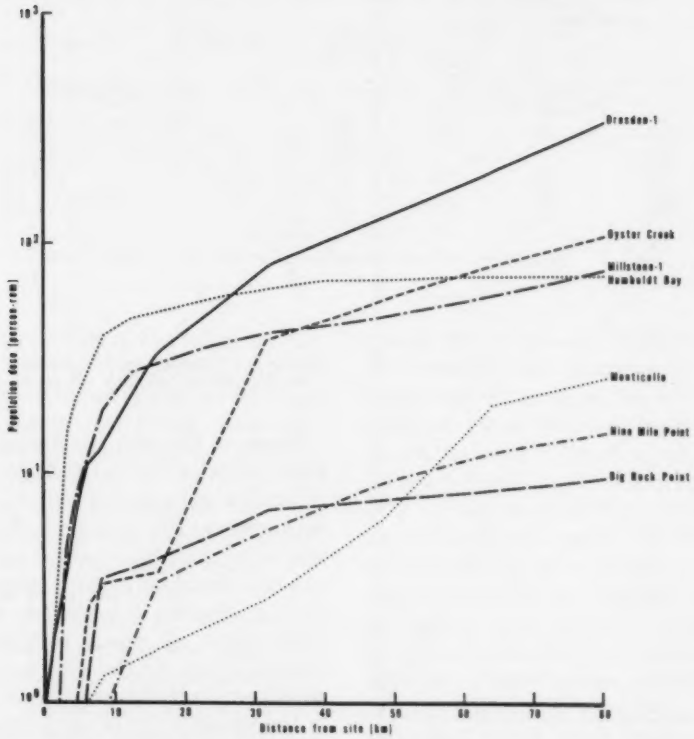

Figure 6. Growth in cloud gamma population dose with distance

Figure 7 illustrates the calculated concentration of iodine-131 in milk for several effective release heights. Listed in the figure are some of the assumptions used in the calculations. The data apply to a typical maximum wind frequency sector; concentrations in other sectors and for other wind doses may be lower by as much as a factor of 10 and higher by a factor of 5. Displayed are average saturated activity levels; levels may be substantially higher and lower over periods of several days depending upon local weather conditions.

As illustrated in figure 8, 50 to 70 percent of the iodine-131 release leaves the 50-mile radius considered in the computer runs. Because of the latter observation, it is clear that on an annual average basis, cloud depletion by ground deposition, although considered in AIREM, is not a very important consideration for deposition velocities near the typically assumed value (*11*) of 1 cm/s. A corollary is that calculated ground deposition and milk concentrations (where there are dairy herds) increase monotonically with the deposition velocity assumed in the calculations.

Table 6 presents iodine-131 ground deposition calculations for BWR's operating in 1971. Because of the uncertainty in the deposition velocity assumed for iodine emissions and the lack of cow density and milk pool data, ingestion doses have not been calculated. (Note: for a 1-year-old child, a daily consumption of 1 liter of milk having an iodine-131 concentration of 1 pCi/liter would result in a thyroid dose rate of 5 mrem/yr (*12, 13*).

Inhalation and skin doses

Doses due to inhalation of iodine-131 (where

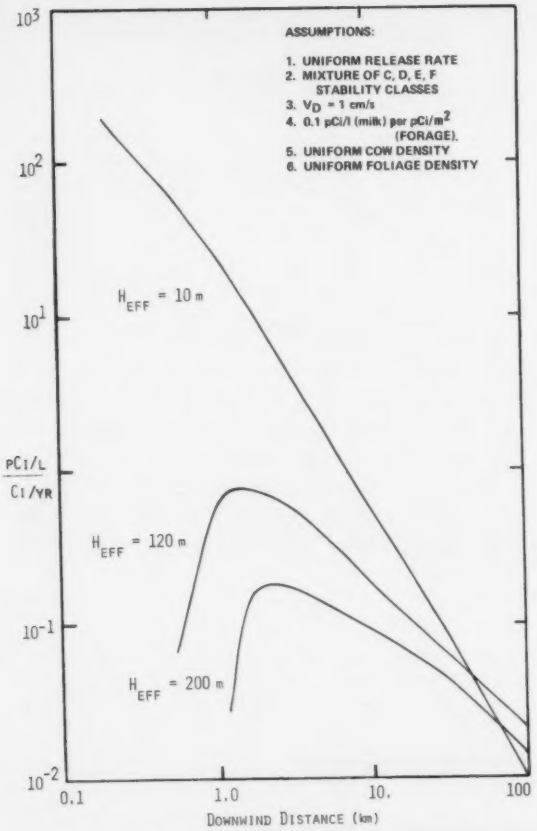

Figure 7. Iodine–131 concentration in milk in a typical high-frequency sector (per curie released)

source terms were provided in reference *5*) are also listed in table 6. These were all small fractions of the cloud gamma doses. Lung doses from rubidium-88 and cesium-138 were not calculated due to the lack of an adequate model.

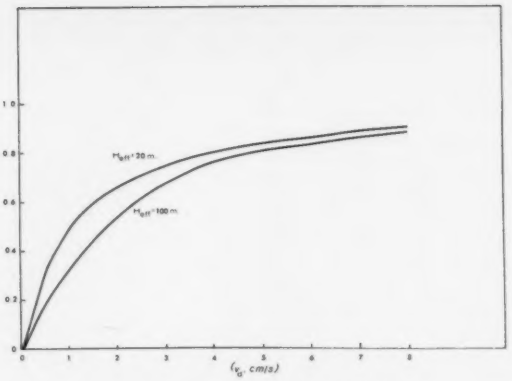

Figure 8. Fraction of release deposited within 50 miles vs. deposition velocity (mixture of stability classes)

Doses to the skin (epidermis) due to external beta particles are not tabulated since these calculations were performed in only a few cases. As a general rule of thumb, for elevated releases the skin population dose was approximately one-half the cloud gamma population dose. However, at the site boundaries, external beta skin doses were all small compared to the cloud gamma doses at the site boundaries. Further, since beta particles are attenuated very strongly in the 'dead' layer of skin (to a depth of 7 mg/cm² or so), the external beta dose delivered to living tissue was very small compared to the cloud gamma dose.

Health effects

Recently, the National Academy of Science Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) has summarized

Table 6. Calculated iodine-131 data (1971 releases)

Facility	H_{eff} (m)	Activity release (curies)	Population dose[a] 80 km (person-rem)	Maximum saturated activity[b] (ground)		
				(pCi/m³)	Distance (km)	Sector
Big Rock Point	100	[c]0.3	0.5	2	3	NNE
Dresden 1	120	.49	1.5	4	2.4	SSE & NW
Dresden 2, 3	200	8.1	10	33	2.4	SSE & NW
Genoa	150	.001		Negligible		
Humboldt Bay	75	.30	.10	11	.6	N
Millstone–1	150	3.94	4.4	20	2.4	ENE
Monticello	100	.04	.05	.9	1.2	SSE
Nine Mile Point	150	.78	.15	7	1.2	N
Oyster Creek	150	1.33	1.5	20	2.4	N

[a] Thyroid dose due to inhalation of iodine–131. An age weighted dose conversion factor of 15.6 mrem/a per pCi/m³ was used (*4*).
[b] Assumes 1 cm/s deposition velocity, stack release.
[c] Estimated release.

Table 7. Calculated health effects from natural background and cloud gamma population doses in 1971

Facility	Population (millions)	Energy produced (GW(e)-yr)	Noble gas emissions (kCi)	Health effects	
				Natural background[a]	Cloud gamma
Big Rock Point	0.15	0.041	273	9.	0.006
Dresden 1, 2, and 3	6.1	.492	1342	370.	.42
Humboldt Bay	.1	.039	502	5.	.043
Genoa (La Crosse)	.12	.025	.56	8.	<.001
Millstone–1	2.5	.39	252	160.	.053
Monticello	2.6	.15	57	140.	.018
Nine Mile Point	1.0	.31	230	65.	.009
Oyster Creek	3.6	.40	516	160.	.081

[a] Gamma background including cosmic ray dose was taken from reference *16*.

the present state of knowledge in radiation risk prediction in their report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation" (*14*). Using the health risk estimates for chronic exposures given in the BEIR Report, the expected number of radiation induced health effects can be calculated for various sources of environmental exposure. Such estimates are based on the conservative, but commonly held assumptions, that radiation effects are directly proportional to the dose and that the number of cancers per rem that have been observed at high doses and dose rates is an adequate predictor of effects per rem at the low doses and dose rates encountered from environmental sources.

The risk values given in the BEIR Report were used to estimate the number of potential health effects from external gamma radiation likely to occur in the population residing within 80 km of operating BWR power stations. Two sources of radiation were considered, natural background radiation, and the external gamma radiation from gaseous atmospheric reactor emissions. The calculated health effects, based upon a risk factor of 7×10^{-4} health effects per person-rem (*15*) are presented in table 7. It is apparent that the number of health effects occurring is a strong function of population size and to a lesser extent dependent on the size and emission control characteristics of the individual reactors.

Discussion of calculational uncertainties

In these calculations, all major physical processes have been taken into account with operational state-of-the-art mathematical techniques. The predominant sources of error lie in the basic assumptions of the invariant wind, the gaussian cloud diffusion model and the diffusion constants used in these calculations. After some 50 years of experience, discrepancies of a factor of 2 (either way) between this theory and field experiments are commonly found within a few kilometers of an emission point (*2, 10, 17*). Considering all error sources, actual site boundary doses were probably within a factor of 3 of the calculated doses. Based upon examination of a few selected cases, maximum doses to real individuals would have been less than the site boundary doses by at least a factor of 2, had occupancy factors, building shielding, the decrease in dose with distance, and locations of nearest residents been considered.

Calculated population doses are even more uncertain. Siting practices in the United States are such that most of the population dose is accumulated at ranges of several tens of kilometers, i.e., at the major population centers. At these ranges, discrepancies between the wind invarient gaussian plume dispersion model predictions and experimental measurements are of the order of a factor of 10 either way (*10*). However, it has recently been shown (*18*) that this model can considerably underestimate dilution at distances of 30 to 50 km. Based upon some preliminary calculations, it was estimated in this study that the calculated population doses could have been overestimated by factors of between 2 and 5.

Risk estimates based on the BEIR Report are by no means precise. For example, predictions of the number of fatal cancers per rem vary by

a factor of about 4 depending on the model used. The risk factor used herein corresponds to the "most likely value" chosen by the BEIR Committee. A more detailed explanation of EPA's application of BEIR data to risk estimates for nuclear facilities has been published in Environmental Analysis of the Uranium Fuel Cycle, Part III, Nuclear Fuel Reprocessing (EPA–520/9–73–003–D) (*15*). As defined in the document, potential health effects from radiation include fatal cancers, nonfatal cancers, and genetic effects in the approximate ratios of 2:2:3, respectively. Somatic effects are assumed to occur within 30 years or so of exposure; genetic effects extend over several generations.

Another potential source of error is the assumption that all radionuclides were emitted from the stacks of these BWR's. This uncertainty affects the iodine deposition calculations more than the cloud gamma dose calculations. Since the facilities do not report releases by release height (nor by chemical form in the case of the iodines), the iodine ground deposition density data in table 6 are uncertain.

Discussion

In 1971, 10 boiling water nuclear power reactors in the United States produced about 1.5 gigawatts-years of electrical energy. These facilities released a total of 3.2 million curies of activity to the air, which resulted in a calculated cloud gamma population dose of 900 person-rem to the residents within 80 km of these facilities. Other pathways were not considered in these calculations. The average whole body dose to individuals within 80 km of all BWR's operating in 1971 was about 0.06 mrem. In all cases considered, calculated health effects due to cloud gamma exposures were small compared to those from natural background.

As illustrated by the data in table 5, krypton-87, krypton-88, its daughter rubidium-88, xenon-135 and xenon-133 were the major contributors to cloud gamma population doses. These isotopes have half-lives of 76 min, 2.8 h, 18 min, 9.2 h, and 5.3 days, respectively. Other contributors have shorter half-lives. The BWR's considered in this report typically employ holdup times on the order of 0.5 hour for those gases released from the air ejector. Figure 9 illustrates the decrease in cloud gamma dose as a function of additional in-plant holdup time, calculated for a particular case. It is apparent that an additional in-plant holdup of even a few hours would significantly reduce radiation exposures to the general population. A holdup of 10 hours could reduce exposures by as much as 90 percent. Upon application of the numerical guidelines proposed by the AEC (*19*), substantial reductions in the population dose per GW(e)-yr should be expected in the future.

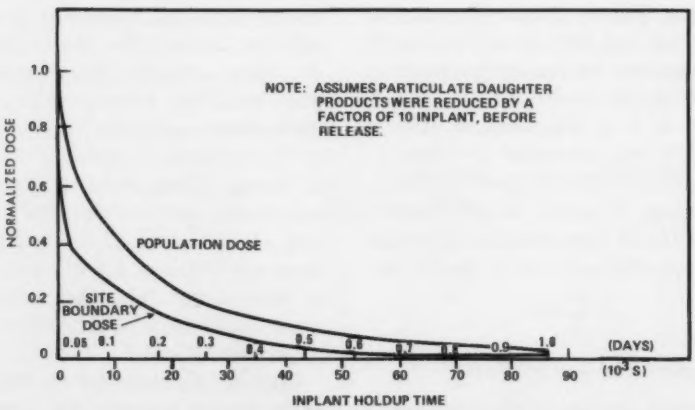

Figure 9. Normalized site boundary and population cloud gamma doses as a function of additional holdup time (1971 Dresden–1 case)

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SECTION I. MILK AND FOOD

Milk Surveillance, January 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Program conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total	
Iodine-131: (96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137: (53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89: (29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90: (32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels < 50 pCi/liter; 5–10% for levels ≥ 50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels < 20 pCi/liter; 4–10% for levels ≥ 20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels < 100 pCi/liter; 4–10% for levels ≥ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels < 100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports*.

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks dis-

Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	4	0	3
Alaska:	Palmer[c]	P	NA	4	0	1
Ariz:	Phoenix[c]	P	NA	0	0	0
Ark:	Little Rock[c]	P	NA	10	0	1
Calif:	Los Angeles[c]	P	NA	0	0	0
	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	0	0	0
	Del Norte	P	13	11	0	5
	Fresno	P	2	1	0	1
	Humboldt	P	3	3	0	1
	Los Angeles	P	2	1	0	2
	Mendocino	P	3	2	0	1
	Sacramento	P	1	2	0	3
	San Diego	P	2	1	0	1
	Santa Clara	P	2	2	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	1	2	0	3
Colo:	Denver[c]	P	NA	3	0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	2
	South Central	R	NS	NA	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NS	NA	NS	0
	West	R	NS	NA	NS	0
Conn:	Hartford[c]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington[c]	P	NA	6	0	2
D.C:	Washington[c]	P	NA	3	0	1
Fla:	Tampa[c]	P	NA	4	14	25
	Central	R	4	5	14	26
	North	R	5	6	25	15
	Northeast	R	6	6	18	29
	Southeast	R	5	5	36	46
	Tampa Bay area	P	5	5	17	28
	West	R	8	8	0	9
Ga:	Atlanta[c]	P	NA	4	0	5
Hawaii:	Honolulu[c]	P	NA	0	0	0
Idaho:	Idaho Falls[c]	P	NA	4	0	0
Ill:	Chicago[c]	P	NA	5	0	1
Ind:	Indianapolis[c]	P	NA	5	0	2
	Central	P	4	5	0	6
	Northeast	P	5	5	15	10
	Northwest	P	7	7	15	9
	Southeast	P	5	6	10	8
	Southwest	P	4	7	0	7
Iowa:	Des Moines[c]	P	NA	4	0	0
	Des Moines	P	4 (3)	5	0 (3)	0
	Iowa City	P	5	5	0	0
	LeMars	P	6	6	0	0
	Little Cedar	P	6	6	0	0
Kans:	Wichita[c]	P	NA	5	0	1
	Coffeyville	P	3	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	P	5	6	13	7
	Hays	P	3	6	0	5
	Kansas City	P	5	5	0	6
	Topeka	P	3	6	10	5
	Wichita	P	6	6	12	7
Ky:	Louisville[c]	P	NA	5	0	2
La:	New Orleans[c]	P	NS	7	NS	1
Maine:	Portland[c]	P	NA	4	0	14
Md:	Baltimore[c]	P	NA	6	0	3
Mass:	Boston[c]	P	NA	7	0	9
Mich:	Detroit[c]	P	NA	6	0	3
	Grand Rapids[c]	P	NA	7	0	1
	Bay City	P	14	10	0	1
	Charlevoix	P	7	9	0	1
	Detroit	P	21	8	0	0
	Grand Rapids	P	23	11	14	3
	Lansing	P	17	11	6	3
	Marquette	P	14	10	0	7
	Monroe	P	6	13	0	1
	South Haven	P	27	13	0	3
Minn:	Minneapolis[c]	P	NA	7	0	1
	Bemidji	P	7	7	0	11
	Duluth	P	15	16	16	17
	Fergus Falls	P	8	6	0	0
	Little Falls	P	NS	17	NS	27
	Mankato	P	5	5	0	0
	Marshall	P	3	3	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
Minn:	Minneapolis	P	9	9	0	0
	Rochester	P	6	6	0	0
Miss:	Jackson[c]	P	NA	8	0	6
Mo:	Kansas City[c]	P	NA	4	0	0
	St. Louis[c]	P	NA	8	0	1
Mont:	Helena[c]	P	NA	2	0	0
Nebr:	Omaha[c]	P	NA	2	0	0
Nev:	Las Vegas[c]	P	NA	5	0	0
N.H:	Manchester[c]	P	NA	6	0	8
N.J:	Trenton[c]	P	NA	5	0	2
N. Mex:	Albuquerque[c]	P	NA	0	0	0
N.Y:	Buffalo[c]	P	NA	5	0	3
	New York City[c]	P	NA	4	0	3
	Syracuse[c]	P	NA	6	0	1
	Albany	P	5	4	0	0
	Buffalo	P	3	5	0	0
	Massena	P	7	7	0	10
	New York City	P	NA	7	14	0
	Syracuse	P	NS	6	NS	0
N.C:	Charlotte[c]	P	NA	7	0	5
N. Dak:	Minot[c]	P	NA	6	0	0
Ohio:	Cincinnati[c]	P	NA	5	0	3
	Cleveland[c]	P	NA	6	0	2
Okla:	Oklahoma City[c]	P	NA	3	0	0
Oreg:	Portland[c]	P	NA	4	0	1
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	P	NA		NA	
Pa:	Philadelphia[c]	P	NA	5	0	2
	Pittsburgh[c]	P	NA	9	0	3
	Dauphin	P	5	4	0	0
	Erie	P	6	6	0	0
	Philadelphia	P	4	4	0	0
	Pittsburgh	P	4	5	0	0
R.I:	Providence[c]	P	NS	4	NS	5
S.C:	Charleston[c]	P	NA	5	0	5
	Chapin	R	NS	8	NS	15
	Clemson	R	NS	8	NS	10
	Columbia	R	7	8	10	11
	Fairfield	R	6	7	10	12
	Hartsville-02	R	NS	7	NS	11
	Hartsville-03	R	NS	16	NS	14
	Lee County	R	NS	8	NS	15
	Oconee County	R	NS	8	NS	9
	Pickens	R	NS	7	NS	8
	Williston	R	NS	7	NS	17
	Winnsboro	R	7	7	11	15
S. Dak:	Rapid City[c]	P	NA	6	0	1
Tenn:	Chattanooga[c]	P	NA	6	0	1
	Knoxville[c]	P	NA	0	0	0
	Memphis[c]	P	NA	6	0	2
	Chattanooga	P	NA	7	0	3
	Clinton	R	NA	6	14	4
	Fayetteville	R	NA	6	6 (2)	3
	Kingston	R	NA	7	5	0
	Knoxville	P	NA	5	19	3
	Lawrenceburg	R	NA	3	0	6
	Nashville	P	NA	4	10	3
	Pulaski	R	NA	6	5	0
	Sequoyah	R	NS	9	NS	6
Tex:	Austin[c]	P	NA	0	0	0
	Dallas[c]	P	NA	4	0	0
Utah:	Salt Lake City[c]	P	NA	2	0	0
Vt:	Burlington[c]	P	NA	4	0	5
Va:	Norfolk[c]	P	NA	6	0	1
Wash:	Seattle[c]	P	NA	1	0	0
	Spokane[c]	P	NA	5	0	0
	Benton County	R	0	0	0	0
	Franklin County	R	NS	1	NS	0
	Longview	R	5	4	17	5
	Sandpoint, Idaho	R	5	5	0	1
	Skagit County	R	4	4	0	0
W. Va:	Charleston[c]	P	NA	7	0	2
Wisc:	Milwaukee[c]	P	NA	4	0	1
Wyo:	Laramie[c]	P	NA	1	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:						
Alberta:	Calgary	P	NA		4	7
	Edmonton	P	NA		6	12
British Columbia:	Vancouver	P	NA		11	13
Manitoba:	Winnipeg	P	NA		6	10
New Brunswick:	Moncton	P	NA		10	9
Newfoundland:	St. John's	P	NA		6	15
Nova Scotia:	Halifax	P	NA		4	10
Ontario:	Ottawa	P	NA		5	6
	Sault Ste. Marie	P	NA		11	16
	Thunder Bay	P	NA		8	11
	Toronto	P	NA		4	6
	Windsor	P	NA		3	6
Quebec:	Montreal	P	NA		NS	
	Quebec	P	NA		15	12
Saskatchewan:	Regina	P	NA		3	7
	Saskatoon	P	NA		6	7
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	10	NS	13
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Kingston	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	1	0	2
PMN network average[d]			NA	4	0	2

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [d].
NA, no analysis.
NS, no sample collected.

cussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for January 1974 and the 12-month period, February 1973 to January 1974. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for January

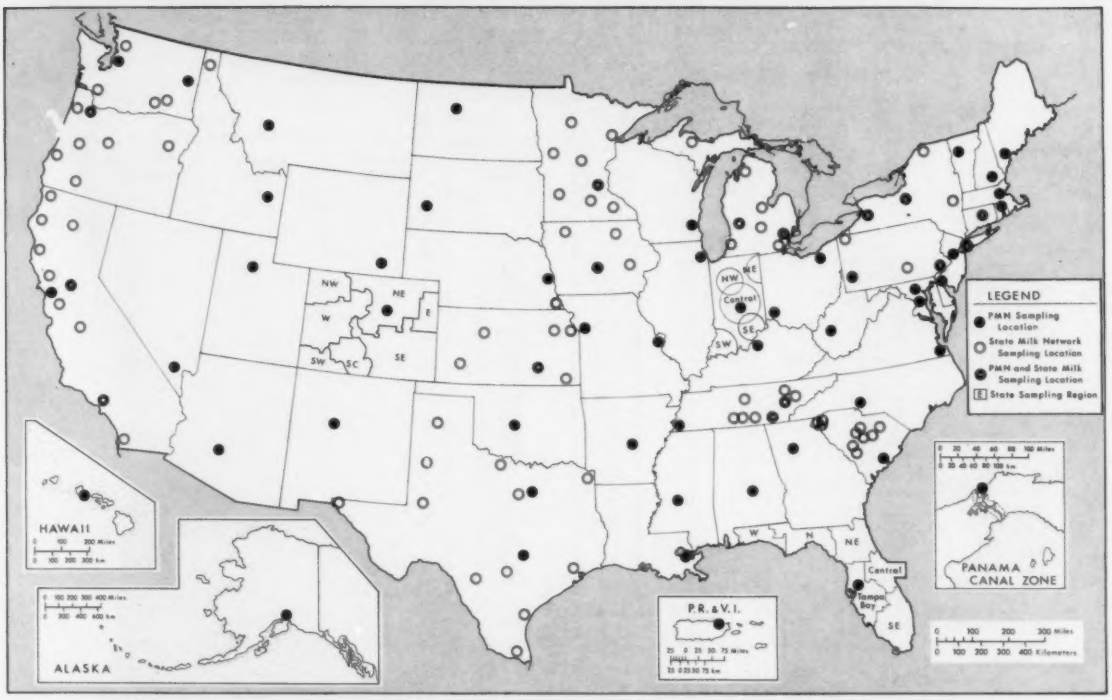

Figure 2. State and PMN sampling stations in the United States

1974 were below the respective practical reporting levels with one exception. The following station average reflects a sample in which strontium-89 was detected: Calif: Del Norte (State), 10 pCi/liter.

Strontium-90 monthly averages ranged from 0 to 27 pCi/liter in the United States for January 1974 and the highest 12-month average was 17 pCi/liter (Little Falls, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 36 pCi/liter in the United States for January 1974, and the highest 12-month average was 46 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report. Table 3 gives the strontium-89 and strontium-90 results of PMN milk samples composited by region.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Table 3. Strontium-90[a] results of PMN milk samples composited by region

EPA region	States located in region	Strontium-90 concentration (pCi/liter)
I	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	4
II	New Jersey, New York, Puerto Rico	3
III	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	6
IV	Alabama, Canal Zone, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	5
V	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	5
VI	Arkansas, Louisiana, New Mexico, Oklahoma, Texas	5
VII	Iowa, Kansas, Missouri, Nebraska	4
VIII	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	3
IX	Arizona, California, Hawaii, Nevada	0
X	Alaska, Idaho, Oregon, Washington	3

[a] All strontium-89 results were less than the practical reporting level (5 pCi/liter).

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

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(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Milk Surveillance Network, First Quarter 1974

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Milk Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV) consists of 24 routine and 1 alternate sampling locations (figure 1) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS).

In the event of a release of radioactivity from the NTS, special sampling within the affected

[1] This network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

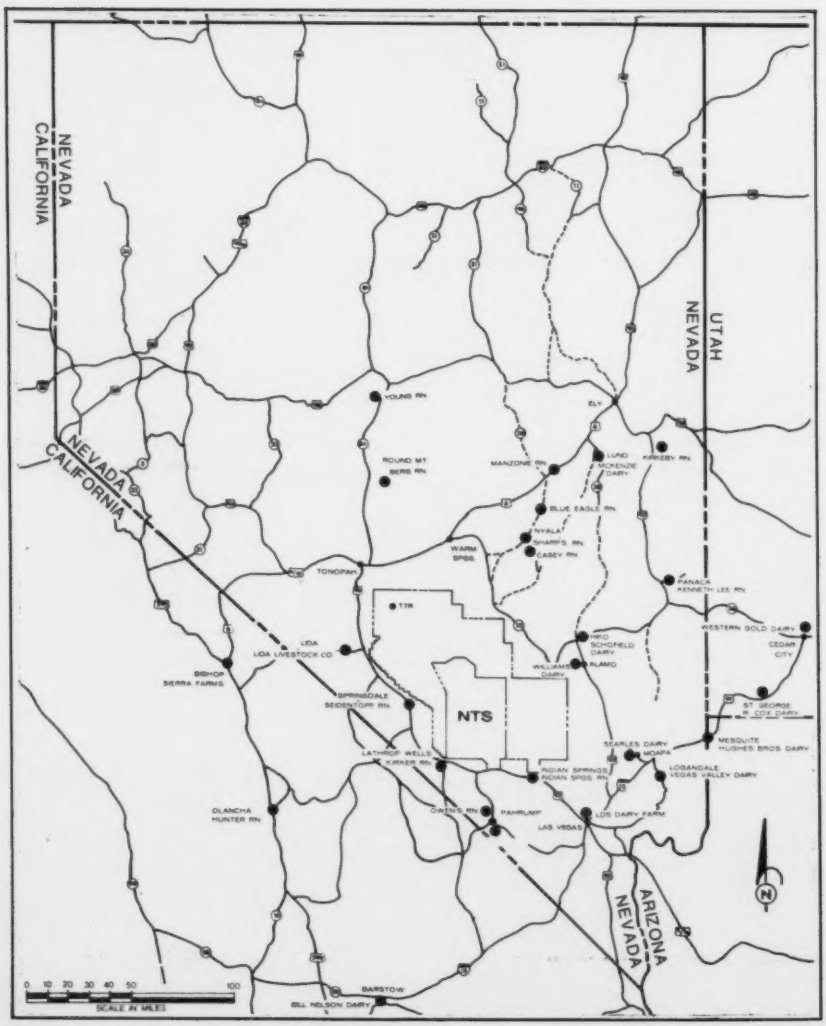

Figure 1. NERC–LV Milk Surveillance Network

Table 1. Milk surveillance results, First Quarter 1974

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)			
			Cesium-137	Strontium-89	Strontium-90	Tritium
California:						
Bishop:						
Sierra Creamery	1/17	11	<10	<2.7	1.4±1.1	NA
Hinkley:						
Bill Nelson Dairy	1/15	12	<10	<2.6	1.5±1.0	NA
Olancha:						
Hunter Ranch	NS					
Nevada:						
Alamo:						
Williams Dairy	NS					
Austin:						
Young's Ranch	1/8	13	<10	<3.4	1.6±1.3	830±250
Currant:						
Blue Eagle Ranch	1/17	13	<10	<2.4	<2.0	NA
Manzonie Ranch	1/16	13	<10	<2.7	2.0±1.1	NA
Hiko:						
Schofield Dairy	1/7	12	<10	<4.2	3.8±1.6	<240
Indian Springs:						
Indian Springs Ranch	1/11	13	<10	<2.9	<1.1	NA
Las Vegas:						
LDS Dairy Farms	1/14	12	<10	<2.9	<1.2	290±240
Lathrop Wells:						
Kirker Ranch	1/11	13	<10	<3.3	<1.3	NA
Lida:						
Lida Livestock Company	1/6	13	<10	<3.7	2.6±1.4	NA
Logandale:						
Vegas Valley Dairy	1/15	12	<10	<5.5	3.0±2.2	NA
Lund:						
McKenzie Dairy	1/16	12	<10	<2.4	2.0±1.0	<230
Mesquite:						
Hughes Bros. Dairy	1/15	12	<10	<3.2	<1.2	<230
Moapa:						
Searles Dairy	1/15	12	<10	<3.6	1.9±1.4	NA
Nyala:						
Sharp's Ranch	1/8	13	<10	<3.6	2.5±1.3	250±240
Pahrump:						
Burson Ranch	1/11	13	<10	<3.2	<1.2	NA
Panaca:						
Kenneth Lee Ranch	1/11	13	<100	<3.3	1.8±1.3	NA
Round Mountain:						
Berg Ranch	1/8	13	<10	<3.5	<1.3	NA
Shoshone:						
Kirkeby Ranch	1/15	13	<10	<2.8	2.5±1.2	NA
Springdale:						
Seidentopf Ranch	1/10	13	<10	<3.3	<1.3	NA
Utah:						
Cedar City:						
Western Gold Dairy	1/16	12	<10	<3.2	3.3±1.3	NA
St. George:						
R. Cox Dairy	1/17	12	<10	<3.1	<1.3	NA

[a] 11–Pasteurized milk.
12–Raw milk from Grade A producer(s).
13–Raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased minimum detectable activity.
NA, no analysis.
NS, no sample.

area is conducted to determine radionuclide concentrations. Additional milk sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the milk results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The analytical results of all milk samples collected in the first quarter of 1974 by NERC–LV are listed in table 1. With the exception of cesium-137 at levels near the minimum detectable concentration (MDC) of 10 pCi/liter, no gamma-emitting fission products were identified by gamma spectrometry in any of the samples collected in the first quarter. Levels of tritium near the MDC for this radionuclide (~ 200 pCi/liter) were also measured by liquid scintillation counting techniques. The highest concentration of tritium during the first quarter was 830 ± 250 pCi/liter.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Institutional Diet	April–June 1973	March 1974
Strontium-90 in Tri-City Diets	1972	December 1973

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommndations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium-90 and alpha-particle emitters, the limit is 1 000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
ERAMS Surface Water and Drinking Water Components	July–September 1973	May 1974
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1970–June 1971	November 1972
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

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(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Water Surveillance Network, First Quarter 1974

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Water Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 59 sampling locations (figures 1 and 2) in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing conducted by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site.

In the event of a release of radioactivity from the NTS, special sampling within the affected area is conducted to determine radionuclide con-

[1] This network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

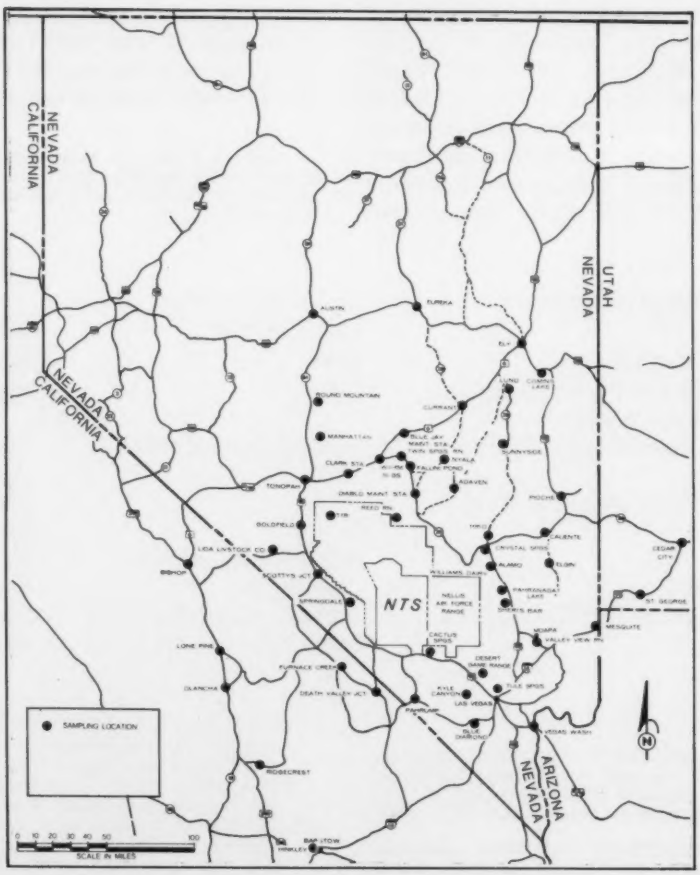

Figure 1. NERC–LV Water Surveillance Network

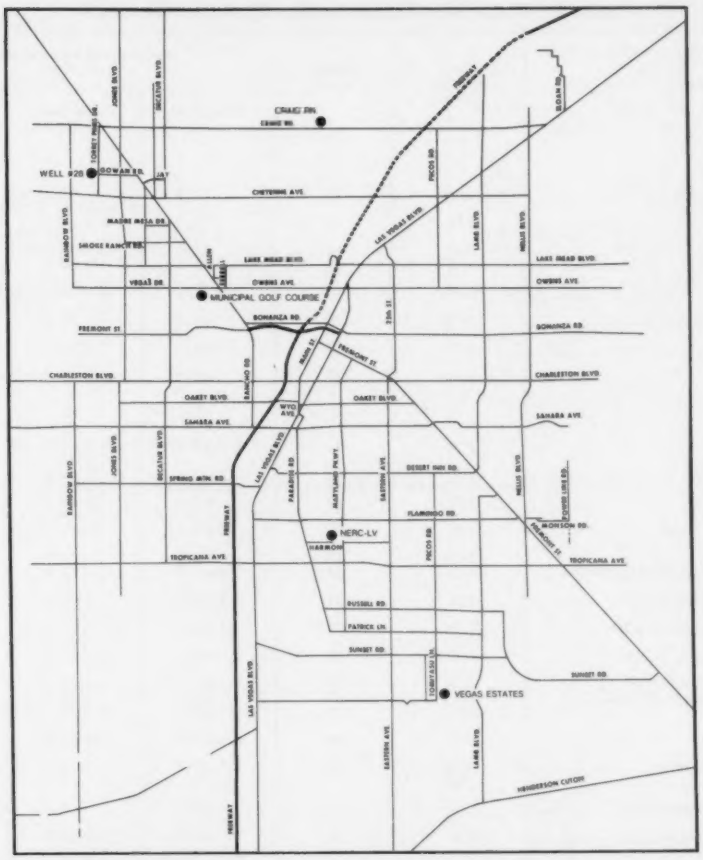

Figure 2. NERC–LV Water Surveillance Network—Las Vegas Valley

centrations. Additional water sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the water results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The routine analytical results of all water samples collected in the first quarter of 1974 by the NERC–LV are listed in table 1. No gamma-emitting fission products were identified by gamma spectrometry in any of the first quarter samples.

Table 1. Water surveillance results, First Quarter 1974

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
California:					
Bishop:					
Fish and Game Office	1/17	23	<1.6	<3.2	NA
Death Valley Junction:					
Lila's Cafe	1/8	23	<2.4	7.5±3.7	<240
Furnance Creek:					
Pond	1/8	21	<4.5	8.4±3.6	NA
Visitor's Center	1/8	27	6.2±4.6	11±3.8	NA
Hinkley:					
Bill Nelson Dairy	1/15	23	7.1±5.0	9.6±3.7	NA
Lone Pine:					
Forest Service Ranger Station	1/16	24	<1.7	<3.2	NA
Olancha:					
Haiwee Reservoir	1/15	21	6.6±4.0	7.9±3.5	NA
Ridgecrest:					
City Hall	1/15	23	<3.6	4.5±3.3	NA
Nevada:					
Adaven:					
Canfield Ranch	1/16	22	4.5±3.0	4.0±3.0	NA
Alamo:					
Pahranagat Lake	1/7	21	<3.6	15±4.0	NA
Sheri's Bar	1/7	23	<2.6	6.8±3.5	NA
Williams Dairy	1/7	23	<2.8	16±4.0	NA
Austin:					
Nevada National Bank	1/9	27	26±6.5	25±4.4	NA
Blue Diamond:					
Post Office	1/11	23	<2.5	<3.2	<240
Blue Jay Highway Maintenance Station	1/17	23	3.3±2.9	7.6±3.3	NA
Cactus Springs:					
Mobil Service Station	1/9	27	2.8±2.2	<3.2	<240
Caliente:					
Agricultural Extension Station	1/10	23	11±4.9	12±3.7	NA
Clark Station:					
Five Mile Ranch	1/17	27	<2.1	6.9±3.2	NA
Currant:					
Currant Ranch Cafe Diablo	1/16	27	7.8±5.1	5.8±3.2	NA
Highway Maintenance Station	1/9	23	<2.4	11±3.7	NA
Reed Ranch	1/7	21	18±6.5	9.3±3.6	NA
Elgin:					
Water tower	1/11	23	6.3±4.7	12±3.8	NA
Ely:					
Chevron Service Station	1/15	24	2.8±2.2	<2.9	NA
Comins Lake	NS				
Eureka:					
Highway Maintenance Station	1/15	24	<2.3	<3.0	NA
Goldfield:					
Chevron Service Station	1/8	23	<2.7	4.0±3.2	NA
Hiko:					
Crystal Springs	1/10	27	9.3±4.6	9.2±3.6	NA
Schofield Dairy	1/7	23	32±9.3	39±5.1	NA
Las Vegas:					
Craig Ranch Golf Course	1/14	23	2.7±2.3	<3.2	<240
Desert Game Range	1/9	23	7.7±3.6	<3.2	<240
Lab I, NERC	1/14	24	<3.0	<3.1	550±240
Lake Mead Vegas Wash	1/14	21	5.7±4.5	6.2±3.5	680±250
Las Vegas Water District Well 28	1/14	23	2.4±2.2	<3.2	<240
Municipal Golf Course	1/14	23	2.7±2.6	4.9±3.3	<240
Tule Springs	1/7	23	4.1±2.7	<3.2	<240
Tule Springs Pond	1/17	21	9.2±4.0	7.1±3.4	NA
Vegas Estates	1/14	23	4.7±4.4	10±3.8	<240
Lida:					
Lida Livestock Company	1/7	27	<2.8	<3.0	NA
Pond at storage tank	1/7	21	<2.3	3.1±3.0	NA
Lund:					
Gardner Grocery	1/16	23	6.3±3.7	<3.0	NA
Manhattan:					
Country store	1/10	23	27±8.3	7.1±3.4	NA
Mesquite:					
Hughes Bros. Dairy	1/15	23	<3.1	8.5±3.4	NA
Moapa:					
Pedersen Valley View Ranch	1/15	27	9.3±5.6	14±4.0	NA
Mt. Charleston:					
Kyle Canyon Fire Station	1/7	27	<1.9	<3.2	<240
Nyala:					
Sharp's Ranch	1/8	23	3.6±2.9	<3.2	NA
Pahrump:					
Texaco Service Station	1/11	23	<1.5	<3.2	NA
Pioche:					
County courthouse	1/10	24	2.8±2.7	8.1±3.5	NA
Round Mountain:					
Mobil Service Station	1/9	27	2.8±2.5	3.9±3.2	NA
Scotty's Junction:					
Holloway Ranch	1/14	23	7.8±5.1	12±3.7	240±230
Springdale:					
Pond	1/8	21	6.8±4.7	10±3.7	NA

See footnotes at end of table.

Table 1. Water surveillance results, First Quarter 1974—continued

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
Nevada:					
Sunnyside:					
Adam McGill Reservoir	1/16	21	6.2±3.7	10±3.4	NA
Wildlife Management Headquarters	1/16	27	2.3±2.1	<2.9	NA
Tonopah:					
Jerry's Chevron Station	1/8	23	3.9±3.2	8.5±3.4	NA
Tonopah Test Range CP-1	1/8	23	5.0±4.0	7.9±3.4	NA
Warm Springs:					
Fallini's Pond	NS				
Service Station and Cafe	1/17	27	13±7.3	24±4.5	NA
Twin Springs Ranch	1/10	23	20±7.3	28±4.6	NA
Utah:					
Cedar City:					
M.D. Baldwin residence	1/16	24	<1.4	<2.9	NA
St. George:					
R. Cox Dairy	1/17	24	3.5±2.1	<2.9	NA

[a] 21–Pond, lake, reservoir, stock tank, stock pond.
22–Stream, river, creek.
23–Well
24–Multiple supply mixed (a water sample consisting of mixed or multiple sources of water such as well and spring).
27–Spring.

[b] Two-sigma counting error provided when available.
NA, not analyzed.
NS, no sample.

ERAMS Surface and Drinking Water Components October-December 1973

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

Present network

The ERAMS Surface and Drinking Water Components are an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 76 quarterly drinking water samples taken from major population centers and selected nuclear facility environs (figure 1). The analyses include (a) tritium on a quarterly basis, (b) gamma scan, gross alpha and gross beta radioactive measurements annually with radium-226 and strontium-90 measurements if the gross alpha or gross beta radio-

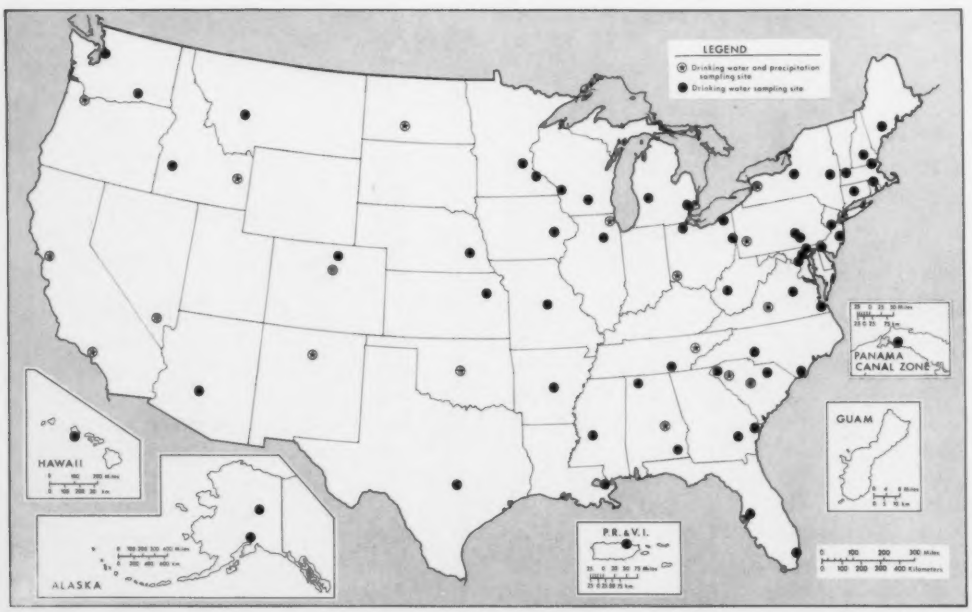

Figure 1. ERAMS drinking water component and precipitation sampling locations

activity exceed 3 or 10 pCi/liter, respectively, and (c) an annual composite for plutonium-238 and -239 on 19 selected sampling locations. The Surface Water Component consists of 55 quarterly surface water samples downstream from nuclear facilities or at a background station (figure 2). The location of the sampling sites was based on all nuclear facilities that were operating, being constructed, or planned through 1976. Tritium analyses are performed quarterly and gamma scans annually. In addition to these components of ERAMS, precipitation samples will be collected at 19 selected locations (figure 1) and tritium measurements are performed on the monthly composite from each station. These 19 locations correspond to air and drinking water sampling locations selected for plutonium analyses. Plutonium-238 and -239 analyses are performed annually on precipitation samples collected in April when elevated levels of rainfall are expected.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the Drinking Water Component stations for October–December 1973. The average tritium concentration was 0.3 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalents from tritium in body water have been based on a relationship derived by Moghissi and Porter (*1*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP recommendation (*2*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*3*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*4*) substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$H\ (\text{mrem/year}) = 0.1C\ (\text{nCi/liter})$$

Where H is the dose equivalent rate and C represents the tritium concentration in body water in nCi/liter.

It can be assumed for the purpose of calcu-

Table 1. ERAMS Drinking Water Component, October-December 1973

Location		Date collected (1973)	Tritium concentration[a] (nCi/liter $\pm 2\sigma$)[b]
Ala:	Dothan	10/15	0
	Montgomery	10/1	0
	Muscle Shoals	NS	
Alaska:	Anchorage	10/17	.3
	Fairbanks	10/28	.8 ±0.3
Ark:	Little Rock	10/5	0
Calif:	Berkeley	10/9	0
	Los Angeles	10/10	0
C.Z:	Ancon	10/23	.3
Colo:	Denver	10/30	.6
	Platteville	NS	
Conn:	Hartford	10/16	.2
Del:	Wilmington	10/24	.3
D.C:	Washington	11/6	.3
Fla:	Miami	10/5	0
	Tampa	10/29	0
Ga:	Baxley	10/9	0
	Savannah	10/9	7.1 ± .3
Hawaii:	Honolulu	10/16	0
Idaho:	Boise	10/12	.5
	Idaho Falls	10/15	.4
Ill:	Chicago	10/25	.2
	Morris	10/23	0
Iowa:	Palo	NS	
Kans:	Topeka	10/10	0
La:	New Orleans	10/17	.2
Maine:	Augusta	10/12	.3
Md:	Baltimore	10/9	.3
	Conowingo	NS	
Mass:	Lawrence	10/5	.3
	Rowe	10/29	0
Mich:	Detroit	10/1	.6
	Grand Rapids	10/10	0
Minn:	Minneapolis	10/12	.5
	Red Wing	10/31	0
Miss:	Jackson	10/5	0
Mo:	Jefferson City	10/18	0
Mont:	Helena	10/24	.4
Nebr:	Lincoln	10/9	.2
Nev:	Las Vegas	10/10	1.0
N.H:	Concord	10/9	.3
N.J:	Trenton	10/31	0
	Waretown	10/18	0
N. Mex:	Santa Fe	10/29	.4
N.Y:	Albany	10/11	.3
	Buffalo	10/11	.4
	New York City	NS	
	Syracuse	10/30	.5
N.C:	Charlotte	10/18	.4
	Wilmington	10/30	.3
N. Dak:	Bismarck	10/12	.6
Ohio:	Cincinnati	10/9	.4
	East Liverpool	NS	
	Painesville	10/12	.3
	Toledo	NS	
Okla:	Oklahoma City	10/8	0
Oreg:	Portland	NS	
Pa:	Columbia	NS	
	Harrisburg	10/10	.3
	Pittsburgh	NS	
P.R:	San Juan	11/13	0
R.I:	Providence	10/10	0
S.C:	Anderson	10/19	.3
	Columbia	10/4	.2
	Hartsville	10/19	.2
	Seneca	10/19	.4
Tenn:	Chattanooga	10/4	0
	Knoxville	10/5	0
Tex:	Austin	10/9	0
Va:	Doswell	NS	
	Lynchburg	NS	
	Norfolk	NS	
Wash:	Richland	NS	
	Seattle	10/10	.2
Wisc:	Genoa	10/18	0
	Madison	10/9	0
Average			0.3

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

Table 2. ERAMS Surface Water Component, October-December 1973

Location		Water source	Facility	Collection date (1973)	Concentration [a] (nCi/liter ±2σ)[b]
Ala:	Decatur	Tennessee River	Browns Ferry, Sequoyah and Oak Ridge	10/16	0.4
	Gordon	Chattahoochie River	Joseph M. Farley	10/15	0
Ark:	Little Rock	Arkansas River	Arkansas Nuclear One	10/ 5	0
Calif:	Clay Station	Folsom S. Canal	Rancho Seco	NS	
	Diablo Canyon	Pacific Ocean	Diablo Canyon	NS	
	Eureka	Humboldt Bay	Humboldt Bay	NS	
	San Onofre	Pacific Ocean	San Onofre	NS	
Colo:	Greely	South Platte River	Fort St. Vrain	10/30	.8
Conn:	East Haddam	Connecticut River	Haddam Neck and Vermont Yankee	10/26	.5
	Waterford	Long Island Sound	Millstone	10/26	0
Fla:	Crystal River	Gulf of Mexico	Crystal River	NS	
	Ft. Pierce	Atlantic Ocean	St. Lucie	NS	
	Homestead	Biscayne Bay	Turkey Point	NS	
Ga:	Baxley	Altamaha River	Edwin I. Hatch	10/ 9	0
Idaho:	Buhl	Snake River	National Reactor Testing Station	10/11	.5
Ill:	Moline	Mississippi River	Quad-Cities, Genoa, Prairie Island and Monticello	11/ 6	.3
	Morris	Illinois River	Dresden and Argonne	10/23	.3
	Zion	Lake Michigan	Zion	10/26	.3
Iowa:	Palo	Cedar River	Duane Arnold	NS	
La:	New Orleans	Mississippi River	(Several)	10/ 5	0
Maine:	Wiscasset	Montseway Bay	Maine Yankee	10/ 9	.4
Md:	Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	10/16	.4
	Lusby	Chesapeake Bay	Calvert Cliffs	10/23	.3
Mass:	Plymouth	Plymouth Bay	Pilgrim	10/10	.3
	Rowe	Deerfield River	Yankee	10/ 8	4.7 ±0.3
Mich:	Bridgman	Lake Michigan	Donald C. Cook	10/ 9	.4
	Charlevoix	Lake Michigan	Big Rock Point	10/ 7	.3
	Monroe	Lake Erie	Enrico Fermi	10/ 8	.3
	South Haven	Lake Michigan	Palisades	10/ 9	.3
Minn:	Monticello	Mississippi River	Monticello	10/ 4	.6
	Red Wing	Mississippi River	Prairie Island and Monticello	10/31	.4
Nebr:	Rulo	Missouri River	Fort Calhoun & Cooper	10/18	.3
Nev:	Boulder City	Colorado River	Background	10/ 4	.7
N.J:	Bayside	Delaware River	Salem	10/18	.2
	Oyster Creek	Toms River	Oyster Creek	10/18	0
N.Y:	Ossining	Hudson River	Indina Point	10/12	.4
	Oswego	Lake Ontario	Nine Mile Point, James A. Fitzpatrick and R. E. Ginna	10/ 3	.5
	Poughkeepsie	Hudson River	Background	10/ 3	0
N.C:	Charlotte	Catawba River	Wm. B. McGuire	10/18	.3
	Southport	Atlantic Ocean	Brunswick	10/ 1	0
Ohio:	Oak Harbor	Lake Erie	Davis-Besse	NS	
Oreg:	Westport	Columbia River	Trojan and Hanford	NS	
S.C:	Allendale	Savannah River	Savannah River Plant and Oconee	10/25	9.4 ± .4
	Hartsville	Lake Robinson	H. B. Robinson	10/19	0
Tenn:	Daisy	Tennessee River	Sequoyah and Oak Ridge	11/14	0
	Kingston	Clinch River	Oak Ridge	10/ 5	2.4 ± .3
Tex:	El Paso	Rio Grande	Los Alamos	10/ 4	.3
Vt:	Vernon	Connecticut River	Vermont Yankee	10/ 4	.2
Va:	Mineral	North Anna River	North Anna	NS	
	Newport News	James River	Surry	10/ 2	0
Wash:	Northport	Columbia River	Background	11/24	.8
	Richland	Columbia River	Hanford	10/ 1	.6
W. Va:	Wheeling	Ohio River	Shippingport and Beaver Valley	10/ 9	0
Wisc:	Two Creeks	Lake Michigan	Point Beach and Kewaunee	10/ 8	.3
	Victory	Mississippi River	Genoa, Prairie Island and Monticello	10/ 8	.4
Average					0.6

[a] The minimum detection limit for all samples in 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.
NS, no sample.

lating dose to members of the population that if the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also if that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in drinking water was 7.1 nCi/liter during the fourth quarter. This corresponds to a dose of 0.7 mrem/a.

The tritium concentrations for the Surface Water Component samples are given in table 2. The highest tritium concentration was 9.4 nCi/liter for the quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.9 mrem/a.

The monthly analyses for tritium in precipi-

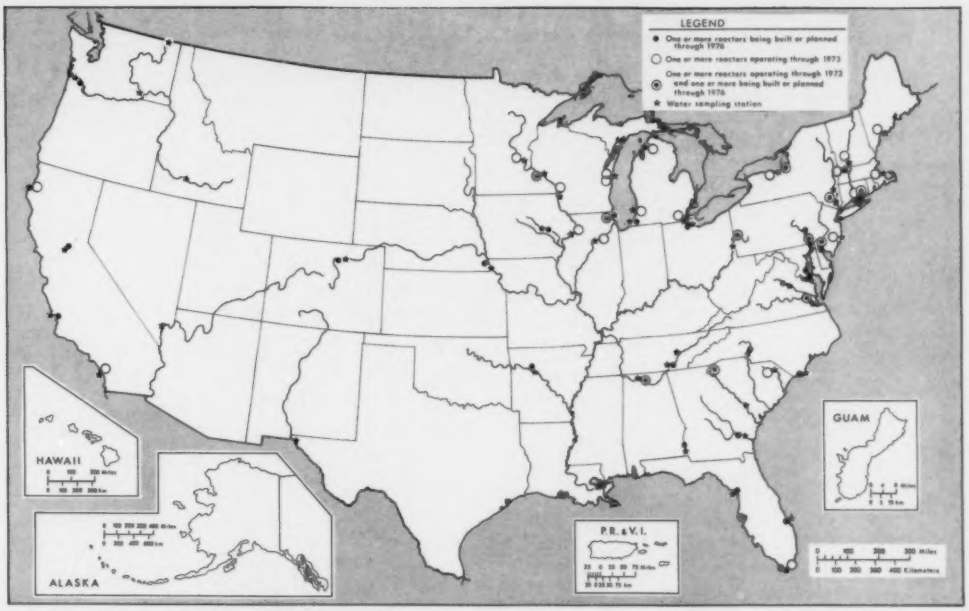

Figure 2. ERAMS surface water component sampling stations

tation samples at the selected stations are shown in table 3.

Table 3. Tritium concentration in precipitation October-December 1973

Location		Tritium concentration[a] (nCi/liter ±2σ)		
		October	November	December
Ala:	Montgomery	0	0.5	0.4
Calif:	Berkeley	0	0	.2
	Los Angeles	NS	NS	NS
Colo:	Denver	0	.3	0
Idaho:	Idaho Falls	NS	NS	NS
Ill:	Chicago	NS	NS	NS
Nev:	Las Vegas	NS	NS	NS
N.Mex:	Santa Fe	NS	NS	NS
N.Y:	Buffalo	NS	.4	0
	New York City	NS	NS	NS
N. Dak:	Bismarck	0	0	0
Ohio:	Cincinnati	NS	NS	NS
Okla:	Oklahoma City	NS	NS	NS
Oreg:	Portland	NS	NS	NS
Pa:	Pittsburgh	NS	NS	NS
S.C:	Anderson	NS	NS	NS
	Columbia	.3	.7	.4
Tenn:	Knoxville	NS	NS	NS
Va:	Lynchburg	NS	NS	NS

[a] The minimum detection limit for these samples was 0.20 nCi/liter All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.
NS, no sample.

Other coverage in *Radiation Data and Reports:*

Period	Issue
October–December 1972	May 1973
January–March 1973	July 1973
April–June 1973	October 1973
July–September 1973	May 1974

REFERENCES

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(2) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965), ICRP Publication 9 (1969).

(3) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Basic radiation protection criteria, NCRP Report No. 39. National Council on Radiation Protection and Measurements, Washington, D.C. 20008 (January 15, 1971).

(4) INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS. Radiation quantities and units, ICRU Report No. 19. International Commission on Radiation Units and Measurements, Washington, D.C. 20014 (July 1972).

Radioactivity in New York State Surface Water January-December 1972

Bureau of Radiological Pollution Control
N.Y.S. Department of Environmental Conservation

In 1955, New York State began a program to determine the amount of radioactivity in water used for public consumption. Radioactivity in water may arise from any one or a combination of the following sources: the natural mineral content of water (background), atmospheric fallout, or nuclear industry operations.

Analytical procedures

Analysis of samples was performed by the Radiological Sciences Laboratory of the New York State Department of Health. The procedures described below were used to perform the indicated analyses.

A gross beta determination is made on a measured quantity of water, usually 250 ml. The sample residue is analyzed for its gross beta component in an end window, gas-flow proportional counter.

Strontium and alkaline earths are precipitated as carbonates from a 1-liter sample. The strontium fraction is separated from calcium and barium by ion exchange separation on AG 50W–x8 from EDTA solution and subsequent elution with 1.5 HCl. The eluate is evaporated to dryness, taken up in water and $SrNO_3$ precipitated. Strontium is reprecipitated as $SrCO_3$ for gravimetric determination of recovery, then redissolved and held for yttrium-90 ingrowth.

Following yttrium-90 ingrowth, yttrium is precipitated as the hydroxide, purified by TBP extraction and back-extracted into water, reprecipitated, weighed and counted as Y_2O_3. Strontium is precipitated as the carbonate from

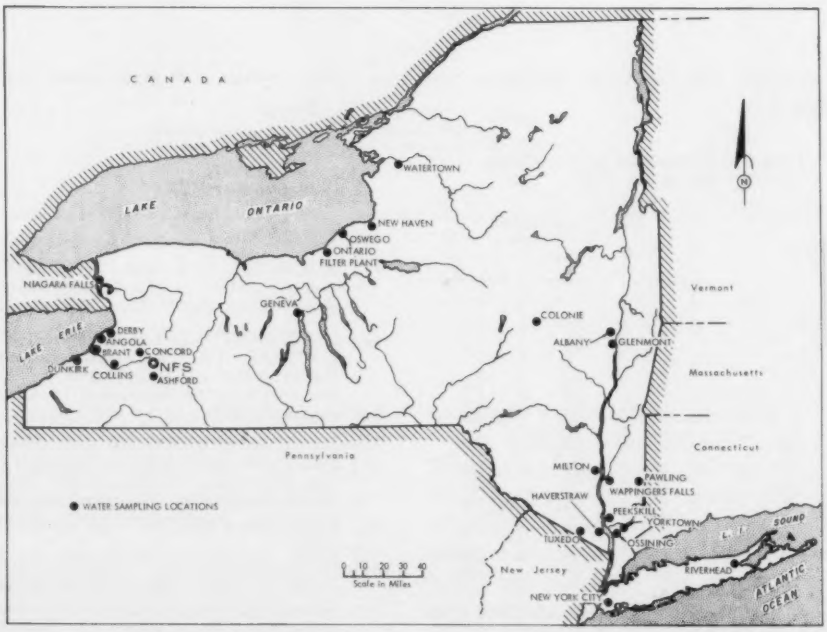

Figure 1. New York water sampling locations

Table 1. Gross beta radioactivity in New York surface waters,[a] January-December 1972

Location	Gross beta radioactivity (pCi/liter)							
	January-March 1972				April-June 1972			
	Number of Samples	Average	Maximum	Minimum	Number of Samples	Average	Maximum	Minimum
Albany	3	3	3	2	3	2	3	2
Angola (Angola Water Treatment Plant)	13	7	12	5	11	7	9	5
Ashford (Buttermilk Creek at Fox Valley Road)	3	5	6	5	3	3	6	ND
(Buttermilk Creek at Thomas Corners)[b]	13	1 434	5 447	198	13	1 307	3 172	185
(Cattaraugus Creek at Bigelow Bridge)	3	6	14	ND	4	20	77	ND
Colonie (Filtration Plant)	13	5	10	2	13	4	6	3
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	146	266	60	13	117	180	17
Daily continuous sample	63	140	840	46	64	122	628	11
Derby (Sturgeon Point)	12	6	8	4	13	6	13	ND
Dunkirk (Dunkirk Filtration Plant)	13	5	7	3	13	4	7	ND
Geneva (Seneca Lake)	3	4	6	3	3	7	8	5
Glenmont (Hudson River)	13	3	5	ND	12	4	6	3
Haverstraw (Iona Filtration Gallery)	1	6			1	2		
Milton (Glowegee Creek at Rt. 50)	4	2	3	2	2	5	5	4
New Haven (Demster Beach Road)	2	5	5	4	2	5	5	4
New York City	6	4	5	2	5	3	6	2
Niagara Falls (West Branch Niagara River)	5	4	5	3	3	4	4	4
Ontario (Ontario Filtration Plant)	14	5	6	3	11	4	6	ND
Ossining (Hudson River at Sing Sing)	15	12	32	ND	13	6	27	3
(Indian Brook Reservoir- raw)	3	4	4	3	3	4	5	3
(Indian Brook Reservoir-treated)	3	4	4	3	3	4	4	3
Oswego (City Hall tap)	7	4	6	3	6	3	5	ND
Pawling (Pond at United Nuclear)	5	3	4	2	3	5	5	4
Peekskill (Camp Field Filter Plant-raw)	3	4	5	3	3	4	5	3
(Camp Field Filter Plant-treated)	3	2	3	ND	3	3	3	2
(Hudson River at Standard Brands)	15	5	15	ND	12	4	16	ND
Rhinecliff (Hudson River)	11	3	6	2	12	3	7	ND
Riverhead (Peconic River)	3	4	5	2	3	4	5	3
Tuxedo (Indian Kill, 150 feet below reservoir)	3	5	5	4	3	4	6	3
Wappinger (Hudson River)	11	4	7	2	12	4	9	ND
Watertown (Black River)	3	3	3	2	3	4	5	3
Yorktown (Croton Reservoir—inlet)	3	3	3	2	3	6	8	5
(Croton Reservoir-deep water)	3	3	4	3	3	4	5	3

Location	July-September 1972				October-December 1972			
	Number of Samples	Average	Maximum	Minimum	Number of Samples	Average	Maximum	Minimum
Albany	3	3	5	2	3	2	2	2
Angola (Angola Water Treatment Plant)	14	5	10	3	11	5	6	2
Ashford (Buttermilk Creek at Fox Valley Road)	3	2	5	ND	3	5	6	4
(Buttermilk Creek at Thomas Corners)[b]	13	4 226	10 592	1 590	13	612	1 670	52
(Cattaraugus Creek at Bigelow Bridge)	3	8	16	ND	3	5	7	2
Colonie (Filtration Plant)	13	4	7	3	13	3	6	2
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	329	620	151	13	86	193	14
Daily continuous sample	63	322	714	120	60	81	240	9
Derby (Sturgeon Point)	13	5	6	4	10	5	6	3
Dunkirk (Dunkirk Filtration Plant)	13	4	7	2	11	4	6	3
Geneva (Seneca Lake)	3	5	9	ND	3	3	5	ND
Glenmont (Hudson River)	11	3	4	2	12	4	6	2
Haverstraw (Iona Filtration Gallery)	NS				NS			
Manorville (Peconic River)	NS				3	10	12	7
Milton (Glowegee Creek at Rt. 50)	2	3	3	2	3	3	4	2
New Haven (Demster Beach Road)	3	4	4	4	3	5	6	5
New York City	5	4	5	3	4	2	3	ND
Niagara Falls (West Branch Niagara River)	3	4	5	3	2	4	4	3
Ontario (Ontario Filtration Plant)	13	4	6	3	12	4	8	2
Ossining (Hudson River at Sing Sing)	13	23	66	ND	12	21	68	ND
(Indian Brook Reservoir-raw)	3	4	5	3	3	4	4	3
(Indian Brook Reservoir-treated)	3	3	4	3	3	3	3	2
Oswego (City Hall tap)	6	4	5	3	6	4	5	3
Pawling (Pond at United Nuclear)	1	2			NS			
Peekskill (Camp Field Filter Plant-raw)	3	3	4	3	3	2	3	2
(Camp Field Filter Plant-treated)	3	3	3	2	3	2	3	2
(Hudson River at Standard Brands)	11	14	57	2	12	11	32	ND
Rhinecliff (Hudson River)	13	4	16	ND	12	4	11	ND
Riverhead (Peconic River)	3	6	8	4	NS			
Tuxedo (Indian Kill, 150 feet below reservoir)	3	3	5	2	3	2	3	2
Wappinger (Hudson River)	13	2	5	ND	12	4	15	ND
Watertown (Black River)	3	3	4	2	2	3	3	3
Yorktown (Croton Reservoir inlet)	3	3	6	2	3	3	3	3
(Croton Reservoir-deep water)	3	2	2	2	3	3	4	3

[a] Excluding tritium.
[b] This station is on the Nuclear Fuels Services reprocessing plant site.
ND, nondetectable.
NS, no sample

Table 2. Strontium concentration of New York surface waters, January-December 1972

Location	Strontium-89 (pCi/liter)				Strontium-90 (pCi/liter)			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Ashford (Buttermilk Creek at Thomas Corners Road)	NS				52	95	357	ND
(Cattaraugus Creek at Bigelow Bridge)	NS				13	ND	8	ND
Concord (Cattaraugus Creek at Springville Dam-weekly composite sample)	NS				52	9	47	ND
(Cattaraugus Creek at Springville Dam-daily continuous sample)	1	ND			33	13	55	ND
New Haven (Demster Beach Road)	NS				1	ND		
Niagara Falls (West Branch of Niagara River)	2	ND	ND	ND	2	ND	ND	ND
Ossining (Hudson River at Sing Sing)	12	ND	ND	ND	53	ND	5	ND
Peekskill (Hudson River at Standard Brands)	12	ND	ND	ND	50	ND	4	ND

NS, no sample.
ND, nondetectable.

the ingrowth solution, reprecipitated as $SrSO_4$, weighed and counted. The strontium-90 activity is calculated from a least squares fit of the yttrium-90 decay data. The strontium-89 activity is determined by subtraction of strontium-90 and yttrium-90 activity from the total strontium-90 activity following appropriate efficiency corrections. If strontium-90 only is required, the ion exchange step is omitted and the recovery determined radiometrically using strontium-89 spike.

Chemical recovery is between 70 and 75 percent and results in a minimum detectable activity for strontium-90 of 1 pCi/liter ± 100 percent at the 95 percent confidence level. The strontium-90 detection limit varies according to the strontium-89/strontium-90 activity ratio, but generally approaches 3 pCi/liter ± 100 percent.

Tritium in water is determined by liquid scintillation counting. The vacuum distillation separates tritium from other interfering radionuclides and removes chemical and/or physical quenching agents. An aliquot of the distillate is mixed with an organic scintillator and counted for 50 minutes in a liquid scintillation spectrometer. Water known to be of low tritium content is used as a background sample. The degree of quenching in a sample is determined by an external standardization source.

The quench factor is used to determine the counting efficiency and the tritium activity in the sample calculated. Analysis of a 10 ml aliquot of the distillate results in a sensitivity of approximately 500 pCi/liter. The sensitivity of the method is defined as that value at which the error at the 95 percent confidence limit equals the measured value, i.e., 100 percent error.

Discussion and results

The concentrations of radionuclides in most water samples throughout the State were low with exception of the water immediately downstream of the Nuclear Fuel Services fuel reprocessing plant (NFS) discharge (figure 1).

Two daily samples from Cattaraugus Creek at Springville Dam, Site 042 exceeded 600 pCi/liter of gross beta radioactivity which is considered to be the allowable AEC limit for a single sample without making a specific isotopic analysis.

The number of samples, quarterly average, maximum and minimum gross beta and strontium concentrations in New York surface water for January–December 1972 are given in tables 1 and 2.

Tritium concentration values for January–December 1972 are given in table 3. Tritium, the radioactive isotope of hydrogen, a very low energy beta-particle emitter, is released to the water courses during the reprocessing of nuclear fuel. The tritium concentrations in Cat-

Table 3. Tritium concentrations of New York surface waters, January-December 1972

Location	Tritium concentration (pCi/liter)							
	January-March 1972				April-June 1972			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Albany	3	ND	ND	ND	3	ND	ND	ND
Angola (Angola Water Treatment Plant)	4	ND	ND	ND	3	ND	ND	ND
Ashford (Buttermilk Creek at Fox Valley Road)	3	ND	ND	ND	3	ND	ND	ND
(Buttermilk Creek at Thomas Corners)[a]	13	24.7	90.2	4.7	13	26.6	89.1	ND
(Cattaraugus Creek at Bigelow Bridge)	3	ND	ND	ND	4	ND	ND	ND
Colonie (Filtration Plant)	3	ND	.6	ND	3	ND	ND	ND
Concord (Cattaragus Creek at Springville Dam):								
Weekly composite sample	13	3.2	5.5	1.2	13	2.1	4.8	ND
Daily continuous sample	63	3.2	9.1	ND	64	2.2	12.7	.5
Derby (Sturgeon Point)	3	ND	ND	ND	4	ND	ND	ND
Dunkirk (Dunkirk Filtration Plant)	3	ND	ND	ND	4	ND	ND	ND
Geneva (Seneca Lake)	3	ND	.7	ND	3	ND	ND	ND
Milton (Glowegee Creek at Rt. 50)	4	ND	ND	ND	2	ND	ND	ND
New Haven (Demster Beach Road)	2	ND	ND	ND	2	ND	ND	ND
Ontario (Ontario filter plant)	14	ND	ND	ND	10	ND	.9	ND
Ossining (Hudson River at Sing Sing)	3	ND	ND	ND	2	ND	ND	ND
Oswego (City Hall tap)	4	ND	ND	ND	3	ND	.7	ND
Pawling (pond at United Nuclear Corp.)	NS				2	ND	ND	ND
Peekskill (Hudson River at Standard Brands)	4	ND	ND	ND	3	ND	ND	ND
Rhinecliff (Hudson River)	11	ND	ND	ND	12	ND	ND	ND
Riverhead (Peconic River)	3	ND	ND	ND	3	ND	ND	ND
Tuxedo (Indian Kill, 150 feet below Reservoir)	3	ND	ND	ND	3	ND	ND	ND
Wappinger (Hudson River)	10	ND	ND	ND	13	ND	.6	ND
	July-September 1972				October-December 1972			
Albany	3	ND	ND	ND	3	ND	ND	ND
Angola (Angola Water Treatment Plant)	3	ND	ND	ND	2	ND	ND	ND
Ashford (Buttermilk Creek at Fox Valley Road)	3	NS	ND	ND	3	ND	ND	ND
(Buttermilk Creek at Thomas Corners)[a]	13	30.1	73	6.8	13	9.9	40	ND
(Cattaraugus Creek at Bigelow Bridge)	3	ND	ND	ND	3	ND	ND	ND
Colonie (Filtration Plant)	4	ND	ND	ND	3	ND	ND	ND
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	2.3	5.7	ND	13	1.1	3.6	ND
Daily continuous sample	63	2.4	6.6	ND	60	1.1	5.6	ND
Derby (Sturgeon Point)	3	ND	ND	ND	2	ND	ND	ND
Dunkirk (Dunkirk Filtration Plant)	3	ND	.7	ND	2	ND	ND	ND
Geneva (Seneca Lake)	3	ND	ND	ND	3	ND	ND	ND
Manorville (Peconic River)	NS				3	4.4	5.9	2.2
Milton (Glowegee Creek at Rt. 50)	2	ND	ND	ND	3	ND	ND	ND
New Haven (Demster Beach Road)	3	ND	ND	ND	2	ND	ND	ND
Ontario (Ontario filter plant)	12	ND	.8	ND	12	ND	ND	ND
Ossining (Hudson River at Sing Sing)	4	ND	ND	ND	2	ND	ND	ND
Oswego (City Hall tap)	3	ND	.9	ND	3	ND	.7	ND
Peekskill (Hudson River at Standard Brands)	2	ND	ND	ND	3	ND	ND	ND
Rhinecliff (Hudson River)	13	ND	.8	ND	12	ND	ND	ND
Riverhead (Peconic River)	3	.6	1.9	ND	NS			
Tuxedo (Indian Kill, 150 feet below Reservoir)	3	ND	ND	ND	3	ND	ND	ND
Wappinger (Hudson River)	13	ND	.9	ND	12	ND	ND	ND

[a] This station is on the Nuclear Fuels Services reprocessing plant site.
ND, nondetectable.
NS, no sample.

taraugus and Buttermilk Creeks reflected contributions to the streams from the Nuclear Fuels Services reprocessing plant.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
July–December 1971	August 1973

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Krypton–85 in air	July 1970–1972	March 1974
Mexican air monitoring	July–December 1973	May 1974
Plutonium in airborne particulates	January–March 1973	May 1974
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network January 1974

Eastern Environmental Radiation Facility, Montgomery, Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during January 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, January 1974

Station location [a]	Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
		5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
		Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala: Montgomery	10	1	0	1	0.04	0.02	0.03	127	0.79
Alaska: Anchorage	3				.04	.03	.03		
Calif: Berkeley	9	0	0	0	.06	.02	.04	24	.07
Los Angeles	9	1	0	1	.11	.02	.06		
Colo: Denver	9	1	0	0	.10	.05	.07	18	.56
Idaho: Idaho Falls	8				.09	.02	.05	12	.12
Ind: Indianapolis	6	3	1	2	.05	.03	.04		
Nev: Las Vegas	9	2	0	1	.09	.02	.05		
N. Mex: Santa Fe	6	0	0	0	.08	.04	.07	9	.03
N.Y: Buffalo	9	0	0	0	.17	.02	.05	2	.02
N. Dak: Bismarck	11	7	0	1	.05	.03	.04	4	.10
Ohio: Columbus	9	0	0	0	.08	.03	.05		
Okla: Oklahoma City	1	0	0	0	.04	.04	.04		
Oreg: Portland	22	0	0	0	.06	<.01	.03		
Pa: Harrisburg	19	1	0	0	.07	.02	.04		
S.C: Columbia	8	0	0	0	.09	.02	.05	140	.46
Tex: Austin	3	4	2	3	.21	.01	.09		
Network summary	151	7	0	1	0.21	<0.01	0.05	42	0.27

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network, January 1974

National Environmental Research Center—Las Vegas,[1] Environmental Protection Agency

The Air Surveillance Network,[2] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 Western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radio-activity from the NTS. A complete description of sampling and analytical procedures was presented in the February issue of *Radiation Data and Reports.*

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to one significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to two significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (—0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

[1] Formerly the Western Environmental Research Laboratory.
[2] This network is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

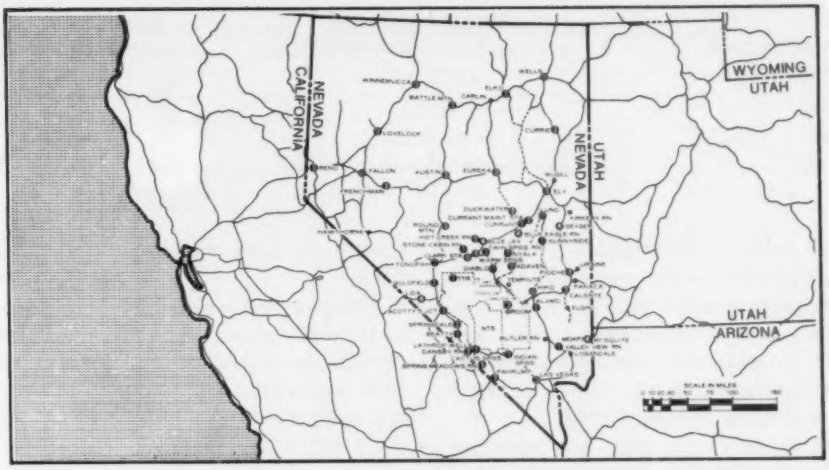

Figure 2. NERC–LV Air Surveillance Network stations in Nevada

Figure 3. NERC–LV Air Surveillance Network stations outside Nevada

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥ 0.05 <0.15	0.1	<0.1
≥ 0.15	As calculated and rounded	$<$calculated MDC

As shown in table 2, the highest gross beta concentration at continuously operated stations within the network was 0.3 pCi/m^3 at Bishop, Furnace Creek and Ridgecrest, Calif. and Pahrump, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during January 1974.

The 72 standby stations were activated on January 14 for 1 week of operation to check equipment and gather background radiation data.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 1. Summary of gross beta radioactivity concentration in air, January 1974

Location		Number of samples	Concentration (pCi/m^3)		
			Maximum	Minimum	Average
Ariz:	Kingman	13	0.2	<0.1	0.1
	Phoenix	3	.2	<.1	.1
	Seligman	13	.2	<.1	.1
	Winslow	3	.2	.1	.1
Ark:	Little Rock	3	<.1	<.1	<.1
Calif:	Baker	13	.2	<.1	.1
	Barstow	13	.2	<.1	.1
	Bishop	13	.3	<.1	.2
	Death Valley Junction	13	.2	<.1	.1
	Furnace Creek	13	.3	<.1	.1
	Indio	3	.1	<.1	.1
	Lone Pine	9	.2	<.1	.1
	Needles	10	.2	<.1	.1
	Ridgecrest	13	.3	<.1	.1
	Shoshone	13	.2	<.1	.1
Colo:	Denver	3	.2	.1	.1
	Durango	2	.2	.1	.2
Idaho:	Boise	3	.1	.1	.1
	Idaho Falls	3	.1	<.1	.1
	Preston	2	.1	.1	.1
	Twin Falls	3	.1	.1	.1
Iowa:	Iowa City	3	.1	.1	.1
	Sioux City	3	.2	<.1	.1
La:	Lake Charles	3	.1	.1	.1
	Monroe	3	.1	<.1	.1
	New Orleans	3	.1	<.1	.1
Minn:	Minneapolis	3	.1	.1	.1
Mo:	Clayton	3	.1	.1	.1
	Joplin	3	.1	.1	.1
	St. Joseph	3	.1	<.1	.1
Nebr:	North Platte	3	.2	<.1	.1
Nev:	Alamo	13	.2	<.1	.1
	Austin	11	.1	<.1	.1
	Battle Mountain	1	<.1	<.1	<.1
	Beatty	13	.2	<.1	.1
	Blue Eagle Ranch (Currant)	13	.2	<.1	.1
	Blue Jay	13	.2	<.1	.1
	Caliente	13	.2	<.1	.1
	Currant Ranch	13	.2	<.1	.1
	Currie	3	.1	.1	.1
	Diablo	13	.2	<.1	.1
	Duckwater	13	.2	<.1	.1
	Elko	3	.1	.1	.1
	Ely	13	.2	<.1	.1
	Eureka	13	.2	<.1	.1
	Fallini's Twin Springs Ranch	13	.2	<.1	.1
	Fallon	3	.2	<.1	.1
	Frenchman Station	3	.2	<.1	.1
	Geyser Ranch (Pioche)	11	.2	<.1	.1
	Goldfield	13	.1	<.1	.1
	Groom Lake	12	.2	<.1	.1
	Hiko	13	.2	<.1	.1
	Indian Springs	13	.2	<.1	.1

Table 1. Summary of gross beta radioactivity concentration in air, January 1974—continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average
Nev:	Las Vegas	22	.2	<.1	.1
	Lathrop Wells	12	.1	<.1	.1
	Lida	13	.2	<.1	.1
	Lockiock	3	.2	<.1	.1
	Lund	13	.2	<.1	.1
	Mesquite	13	.2	<.1	.1
	Nyala	11	.2	<.1	.1
	Pahrump	14	.3	<.1	.1
	Pioche	13	.2	<.1	.1
	Reno	3	.1	.1	.1
	Round Mountain	13	.2	<.1	.1
	Scotty's Junction	12	.2	<.1	.1
	Stone Cabin Ranch	13	.2	<.1	.1
	Sunnyside	13	.1	<.1	.1
	Tonopah	13	.2	<.1	.1
	Tonopah Test Range	11	.2	<.1	.1
	Warm Springs	11	.2	<.1	.1
	Warm Springs Ranch	13	.2	<.1	.1
	Wells	3	.2	.1	.1
	Winnemucca	3	.1	<.1	.1
N. Mex:	Albuquerque	3	.2	<.1	.1
	Carlsbad	2	.3	.2	.2
Okla:	Muskogee	6	.1	<.1	.1
Oreg:	Burns	5	.1	<.1	.1
	Medford	3	.1	<.1	.1
S. Dak	Aberdeen	3	.1	<.1	.1
	Rapid City	3	.1	<.1	.1
Tex:	Abilene	3	.2	.1	.1
	Austin	3	.1	<.1	<.1
	Fort Worth	3	.1	.1	.1
Utah:	Bryce Canyon	3	.1	<.1	.1
	Cedar City	10	.2	<.1	.1
	Delta	8	.2	<.1	.1
	Dugway	3	.2	.1	.2
	Enterprise	3	.2	.1	.2
	Garrison	13	.2	<.1	.1
	Logan	3	.2	.1	.1
	Milford	10	.2	<.1	.1
	Monticello	3	.1	<.1	.1
	Parowan	3	.2	.1	.2
	Provo	3	.1	.1	.1
	Salt Lake City	3	.2	<.1	.1
	St. George	14	.1	<.1	.1
Wash:	Seattle	3	<.1	<.1	<.1
	Spokane	3	.1	<.1	.1
Wyo:	Rock Springs	3	.1	<.1	.1

3. Canadian Air and Precipitation Monitoring Program,[3] January 1974

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May

[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

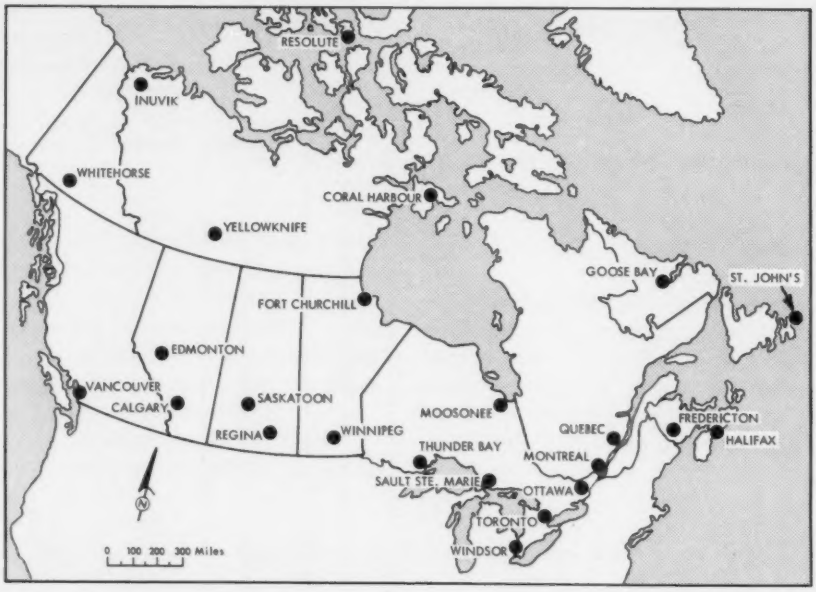

Figure 4. Canadian air and precipitation monitoring program

Table 3. Canadian gross beta radioactivity in surface air and precipitation, January 1974

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.03	0.02	0.03	16.3	0.4
Coral Harbour	5	.05	.04	.05	34.0	.2
Edmonton	5	.05	.03	.04	9.8	.3
Ft. Churchill	4	.05	.01	.03	26.0	.2
Fredericton	5	.03	.03	.03	15.5	1.3
Goose Bay	4	.03	.01	.02	14.8	.3
Halifax	5	.04	.03	.04	11.5	1.1
Inuvik	5	.06	.02	.04	7.9	.3
Montreal	5	.03	.02	.03	14.9	1.0
Moosonee	4	.05	.04	.05	5.8	.3
Ottawa	5	.04	.02	.03	10.2	.6
Quebec	5	.03	.02	.03	9.6	.9
Regina	5	.05	.03	.04	12.1	.4
Resolute	5	.05	.02	.04	NS	NS
St. John's, Nfld	5	.02	.01	.02	NS	NS
Saskatoon	5	.05	.03	.04	7.1	.3
Sault Ste. Marie	5	.04	.02	.03	22.6	1.6
Thunder Bay	4	.04	.03	.04	11.9	.4
Toronto	NS				18.1	1.2
Vancouver	4	.02	.01	.02	11.8	2.1
Whitehorse	5	.05	.03	.04	NS	NS
Windsor	NS				13.6	1.1
Winnipeg	3	.05	.01	.03	8.0	.3
Yellowknife	4	.04	.01	.03	NS	NS
Network summary	102	0.06	0.01	0.04	14.1	0.5

NS, no sample.

1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for January 1974 are presented in table 3.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

4. Pan American Air Sampling Program January 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The January 1974 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, January 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	0			
Colombia:	Bogota	22	0.04	0.00	0.02
Ecuador:	Cuenca	17	.04	.00	.01
	Guayaquil	20	.04	.00	.01
	Quito	11	.01	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	10	.02	.00	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	16	.13	.00	.02
Pan American summary		96	0.13	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 5. Pan American Air Sampling Program stations

5. California Air Sampling Program January 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similar equipment in nearby communities and at several "background" stations.[1]

Figure 6. California air sampling program stations

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for January 1974.

[1] Air samples near nuclear power reactors obtained under contract number AT(49-1)-3549 between the U.S. Atomic Energy Commission and the California Department of Health.

Table 5. Gross beta radioactivity in California air January 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	20	1.22	0.03	0.22
Barstow	29	1.08	.00	.21
Berkeley	30	.24	.00	.11
Diablo Canyon Nuclear Power Plant	8	.22	.02	.11
El Centro	22	.37	.01	.17
Eureka	19	.29	.00	.08
Fresno	12	.24	.03	.12
Humboldt Bay Power Plant: Unit 3	13	.11	.03	.07
Los Angeles	22	.45	.04	.15
Rancho Seco Nuclear Generating Station	13	.28	.00	.13
Redding	14	.31	.08	.19
Sacramento	21	.26	.03	.10
Salinas	22	.92	.01	.18
San Bernardino	20	1.03	.00	.22
San Diego	22	.59	.04	.17
San Luis Obispo	22	.45	.01	.15
San Onofre Nuclear Generating Station	4	.25	.06	.13
Santa Rosa	30	1.23	.00	.13
Summary	343	1.23	0.00	0.15

6. Plutonium in Airborne Particulates April–June 1973

Office of Radiation Programs
Environmental Protection Agency

The Radiation Alert Network (RAN) of the Division of Atmospheric Surveillance, Environmental Protection Agency, routinely collects airborne particulate samples from 11 selected RAN stations for plutonium analyses. The plutonium analyses were initiated in November 1965, and references to the previous results through December 1969 have been published (*1*).

One-half of each individual air filter from the selected stations is sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama. The laboratory analyzes a composite of these samples from each station on a quarterly basis. The results from April-June 1973 are presented in table 6. The minimum detectable activities are 0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively. The volume of air samples varies, generally ranging from 20,000 to 30,000 cubic meters per month.

Table 6. Plutonium in airborne particulates April-June 1973

Location		Plutonium-238 (aCi/m³)	Plutonium-239 (aCi/m³)	$^{239}Pu/^{238}Pu$
Alaska:	Anchorage	(a)	(a)	
Ariz:	Phoenix	4.5±0.8	33.7±3.7	7±2
Colo:	Denver	2.9± .7	26.8±3.2	9±3
Hawaii:	Honolulu	1.0± .5	12.6±2.0	13±6
La:	New Orleans	2.6± .6	16.3±2.1	6±2
Md:	Baltimore	1.5± .5	16.8±2.2	11±4
N.Y:	Buffalo	2.4± .6	17.8±2.3	7±2
N.C:	Gastonia	2.6± .2	17.5±2.3	7±2
S. Dak:	Pierre	8.8±4.5	24.3±7.8	3±2
Tex:	Austin	3.0± .7	22.1±2.7	7±2
Wash:	Seattle	1.4± .6	10.3±2.0	7±3

(a) Insufficient sample volume to obtain detectable levels of plutonium.

Other coverage in *Radiation Data and Reports:*

Period	Issue
April–June 1972	January 1973
July–September 1972	March 1973
October–December 1972	June 1973
January–March 1973	May 1974

REFERENCE

(*1*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–December 1969. Radiol Health Data Rep 11:552–553 (October 1970).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

A summary of the environmental radioactivity data follows for the Hanford Atomics Products Operation.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2] January–December 1971

Battelle Pacific Northwest Laboratories
Richland, Wash.

The primary mission at the Hanford site of the Atomic Energy Commission (AEC) has been the production of plutonium. Activities have included nuclear fuel fabrication, plutonium production and test reactor operation, chemical separations of irradiated fuels, laboratory support and research, waste storage and disposal, and plant support operations. In recent years, privately-owned facilities, including a power generating station, office buildings, and a radioactive waste burial site, have been located within the Hanford site boundaries.

[2] Summarized from Pacific Northwest Laboratory, "Environmental Surveillance at Hanford for 1971," BNWL—1683 (August 1972).

The Hanford site is in a semiarid region of southeastern Washington State (figure 1) where the average rainfall is about 16 cm (6 inches). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site generally have been put under irrigation during the past few years. The plant site covers an area of about 1300 km^2 (500 square miles). The Columbia River flows through the northern edge of the Hanford site and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The population center of primary interest is

Figure 2. Features of Hanford Project and vicinity

the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 100 000.

The farming area closest to the separations facilities is at Ringold, about 20 km (13 miles) away, but much of the land east and south of the project boundary is under cultivation and may be in the path of airborne releases. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the operating reactors. The principal products from the larger farm plots are hay, fruit, beef, and dairy products.

Radioactive wastes continued to be generated during 1971 by the Hanford production reactors, chemical separations plants, and laboratories. High level wastes were concentrated and retained in storage in the chemical separations areas. Controlled releases of low-level wastes, for which concentration and storage were not feasible, were made to the ground, to the atmosphere, and to the Columbia River.

The most significant Hanford contributions

to offsite radioactivity and population doses have in recent years usually originated with reactor once-through cooling water released to the Columbia River (*1*). At one time, nine production reactors, eight with once-through cooling, were in operation at Hanford. Beginning in December 1964, the older reactors with once-through cooling have been deactivated until only two production reactors remained in operation, N and KE. In January 1971, the last production reactor with once-through cooling by river water (KE) was shut down. As a result, the amount of radioactivity released to the Hanford environment, other than to soil within the plant reservation, decreased to relative insignificance. N reactor has a closed primary cooling loop and only releases minor quantities of radioactivity to the river.

Construction of a new reactor, the Fast Flux Test Facility and associated engineering facilities, was well underway in 1971. The reactor location is shown in figure 2. This reactor will use cooling towers for heat dissipation rather than the Columbia River.

The purpose of this annual report is to present a summary and evaluation of the combined offsite effects of effluents released to uncontrolled areas by all Hanford contractors during 1971 in compliance with AECM-0513 (*2*).

Radioactivity in the Columbia River

N reactor, the only production reactor remaining in operation at Hanford after January 1971, uses recirculating, demineralized water as a primary coolant. Waste water containing some radioactive material is discharged

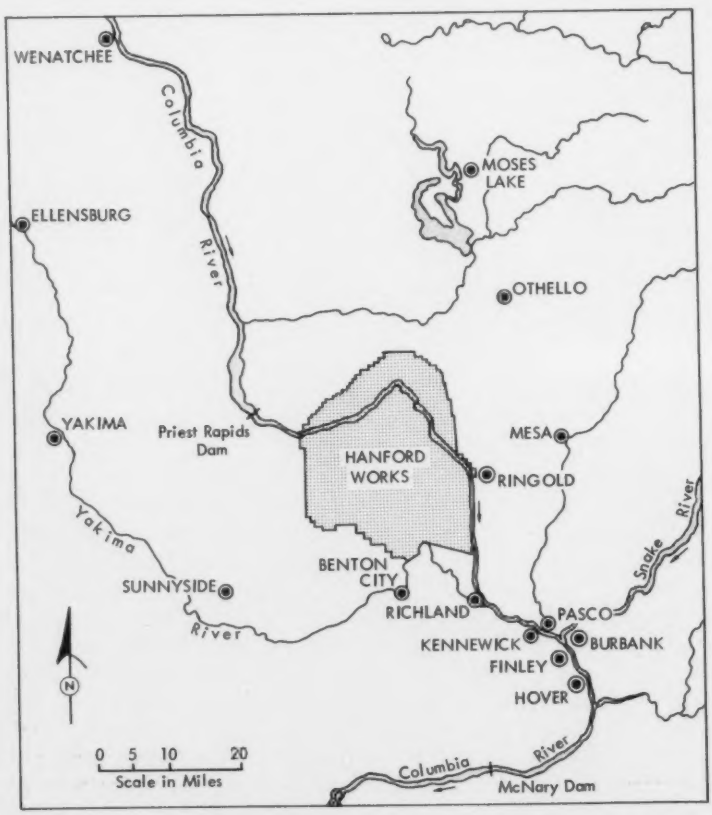

Figure 1. Geographical relationship of Hanford to the Pacific Northwest

to the ground. Many of the radionuclides are shortlived and disappear quickly due to radioactive decay before reaching the river; others are largely absorbed on soil particles and retained in the soil. The small quantities of nuclides reaching the river from N reactor usually have been diluted well below detection level in the river.

Seasonal fluctuations in the flow-rate of the Columbia River affect radionuclide concentrations by varying the quantity of water available for dilution of reactor effluent released to the river. In addition, scouring by high river flows of sediments deposited in reservoirs behind each dam causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments. This has been notably true for scandium-46 and zinc-65. Also affected by the river flow rate is the time required for a specific volume of water to move downstream, which in turn affects the extent of decay of shorter-lived nuclides.

Figure 3 shows the weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams determined from daily average flow rates published by the U.S. Geological Survey (USGS) (*3*). For 1971, the average river flow rate at Priest Rapids was 3820 m^3/s (135 000 cubic feet/s) which was slightly above the 1948–1962 annual average of 3770 m^3/s (133 000 cubic feet/s).

During 1971, samples of Columbia River water were collected at Vernita Toll Bridge near the upstream Hanford boundary and at the Richland water plant intake, near the downstream boundary, as well as McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. Concentrations of radionuclides with relatively short half-lives were measured in monthly "grab" samples.

Sampling traverses across the Columbia River at Richland have indicated a slightly nonuniform distribution of the longer-lived radionuclides at this cross section. Entries of the Yakima River just below Richland and of the Snake River just below Pasco influence the distribution of radionuclides in the Columbia below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries.

Table 1 shows the maximum, minimum, and annual average radionuclide concentration in Columbia River water at Vernita and Richland for 1971. Possible Hanford contribution to the

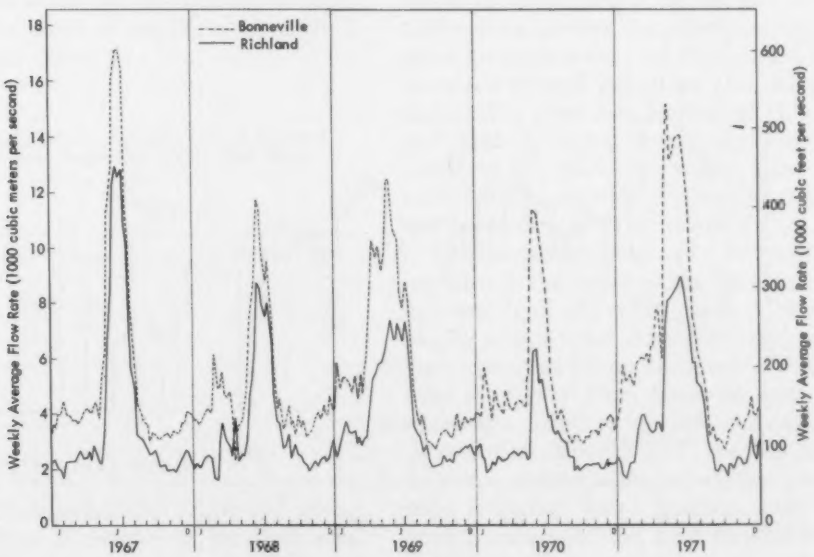

Figure 3. Columbia river flow rates

Table 1. Average concentration of radionuclides in Columbia River water for 1971

Radionuclide	Concentration (pCi/liter)											
	Analytical limit	Vernita			Percent of AEC standard	Richland				Percent of AEC standard	Concentration guide
		Number of samples	Maximum	Minimum	Average		Number of samples	Maximum	Minimum	Average		
Alpha	0.3	12	1.2	0.46	0.84	2.8	12	1.8	0.54	1.01	3.4	30
Tritium	600.0	12	4300	[a]0	1100	.04	12	1500	[a].0	780	.03	3×10^6
Phosphorus-32	6.0	NS					5	50.0	[a].0	2.5	.003	20 000
Scandium-46	8.0	NS					21	50.0	[a].0	5.2	.01	40 000
Chromium-51	40.0	NS					51	590	[a].0	85.0	.004	2×10^6
Zinc-65	10	NS					21	35.0	[a].0	4.5	.005	100 000
Strontium-90	.06	12	.54	.16	.36	.12	12	3.8	[a].32	.85	.28	300
Iodine-131	2.0	NS					47	4.0	[a].0	.41	.01	300
Cesium-137	3.0	3	[a]1.2	[a]0	[b].41	.002	50	28.0	[a].0	5.9	.03	20 000
Uranium (natural)	3.4	NS					5	4.1	3.4	3.4	.02	20 000

[a] Less than analytical limit.
NS, no sample.
[b] Best estimate.

average river radionuclide concentrations is less than 1 percent of the AEC standards for water for all the radioisotopes in table 1, except for alpha which is 3.4 percent of the AEC radiation standard for an unknown mixture of alpha-emitters. Past analyses have shown the natural uranium in the river water to account for at least 90 percent of the total alpha. Figures 4 and 5 show the river transport rates of five radionuclides past Richland. The transport rates at Richland in 1971 for the five radionuclides show the disappearance of the shorter-lived radionuclides following the KE reactor shutdown. Some intermittent transport of previously deposited nuclide-bearing sediments continued to give occasional positive transport values.

Bonneville Dam, approximately 490 km (240 miles) below the N reactor, is the farthest downstream location where river water is

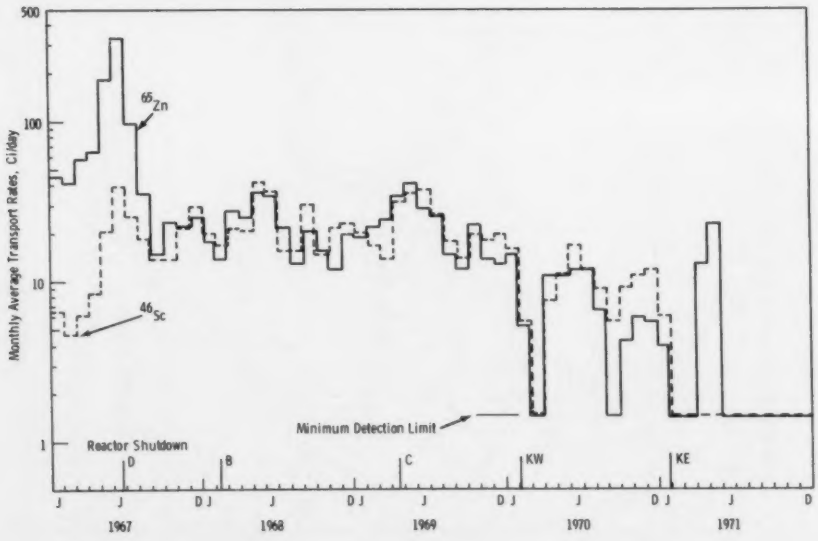

Figure 4. Scandium-46 and zinc-65 transport rates in the Columbia river at Richland (Ci/day)

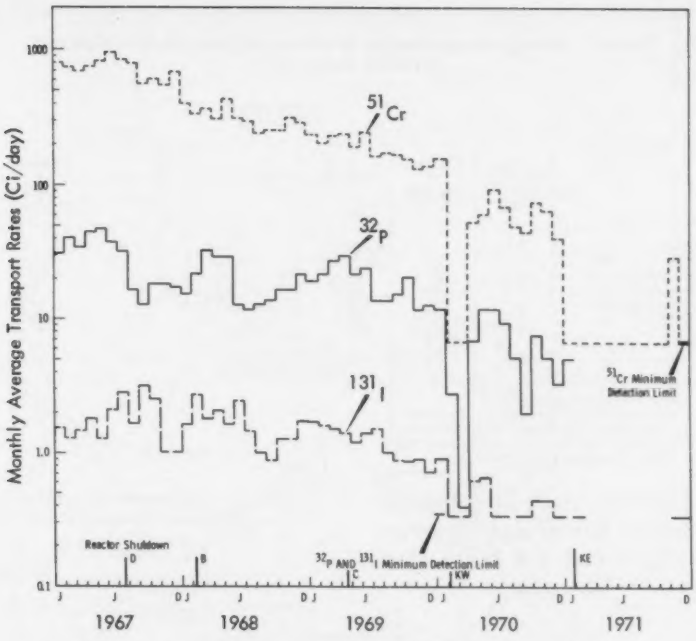

Figure 5. Transport rates in the Columbia river at Richland

sampled routinely as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 2).

Table 2. Annual average transport rate of selected radionuclides past Bonneville Dam, 1967–1971

Radionuclide	Transport rate (Ci/day)				
	1967	1968	1969	1970	1971
Phosphorus-32	12	6.2	7.1	<2.3	NA
Scandium-46	10	7.5	NA	NA	<1.5
Chromium-51	610	200	100	<40	NA
Zinc-65	40	<13	<15	<4.7	<3.7

NA, no analysis.

Radioactivity in drinking water

The City of Richland, about 75 km (45 miles) downstream from N reactor is the first community below the project that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few miles further downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Raney well collectors (infiltration pipes) laid in the riverbed. During 1971, cumulative and grab drinking water samples were collected at the Richland water plant and were analyzed for selected individual radionuclides and gross beta activity (table 3).

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 3 because there can be a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand. Average radionuclide concentrations in Richland drinking water samples were much less than 1 percent of the AEC standards for water except for alpha, which was about 4 percent of the standard for an unknown mixture of alpha

Table 3. Average concentrations of several radionuclides in Richland drinking water, 1971

Radionuclide	Concentration (pCi/liter)					
	Analytical limit (pCi/liter)	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Alpha	0.3	9	2.15	[a] 0.16	[b] 1.2	4
Beta[c]	.02	45	.056	[a] .0	<.016	—
Phosphorus-32	6.0	6	27.2	[a] 3.1	[d] 9.5	.05
Scandium-46	8.0	46	38.3	[a] .0	4.1	.01
Chromium-51	40.0	46	716	[a] .0	110	.006
Cobalt-60	2.0	46	24.1	.0	1.8	.006
Zinc-65	10.0	52	186	[a] .0	12.0	.01
Strontium-90	.06	2	.401	.35	[b] .380	.01
Iodine-131	2.0	6	2.03	[a] .51	[d] <.89	.30

[a] Less than analytical limit.
[b] November and December only.
[c] Counts per minute per milliliter.
[d] January and 1st week of February only.
[e] AEC standard-50 000 pCi/liter.

emitters. As stated earlier, most of the alpha activity in the Columbia River, and therefore Richland drinking water, does not result from Hanford operations.

Groundwater data

An extensive groundwater monitoring program continued to show little, if any, measurable effect on Columbia River quality from low-level wastes released to ground disposal sites within the Hanford plant boundaries. The data from this program continued to be documented separately, the most recent report in this series being BNWL-1649 (4). A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to these confined aquifers, are sampled routinely for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from recent precipitation also can occur. Table 4 shows data from these wells for 1971. The high value for the White Bluffs Association well resulted from one positive sample of 5300 pCi/liter (less than 0.2 percent of the applicable AEC radiation standards), which is not believed to be of Hanford origin since other data from this well and the data from other deep wells closer to plant facilities continued to give negative results.

Table 4. Groundwater tritium analysis from wells in the vicinity of Hanford Plant, 1971

Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard
		Maximum	Minimum	Average	
Webber	2	<940	<520	<730	<.02
Vail	2	<780	<520	<650	<.02
W-15	2	<730	<680	<700	<.02
White Bluffs Association	3	5 300	<510	<2 200	<.07

Radioactivity in the atmosphere

Gaseous effluents from the Hanford chemical separations facilities are released to the atmosphere through tall stacks after passage through high efficiency filters. Laboratory stacks, reactor-building stacks, and stacks from waste storage facilities also may release small amounts of radioactive materials after high efficiency filtration.

During 1971, measurements of airborne iodine-131, total beta, and total alpha were made (as of the end of 1971) at 23 locations around the Hanford reservation. Figure 6 shows the locations of offsite air sampling stations. Figures 7 and 8 show the monthly average iodine-131 and particulate beta radioactivity in the atmosphere from both nearby locations in the direction of the prevailing wind (eastern quadrant) and from more distant perimeter communities.

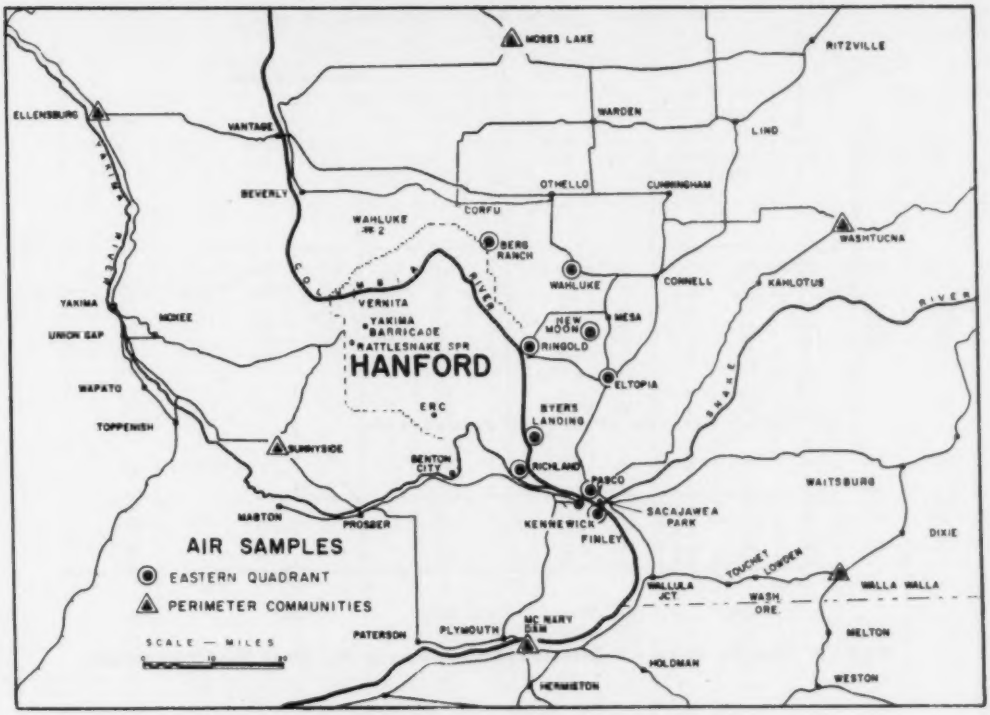

Figure 6. Offsite air sampling locations, Hanford

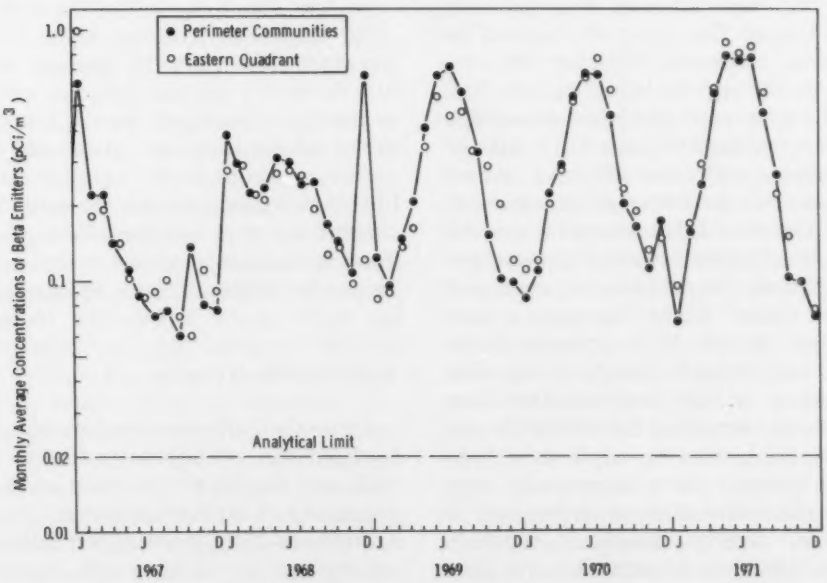

Figure 7. Monthly average particulate total beta concentration in the air of Hanford environs

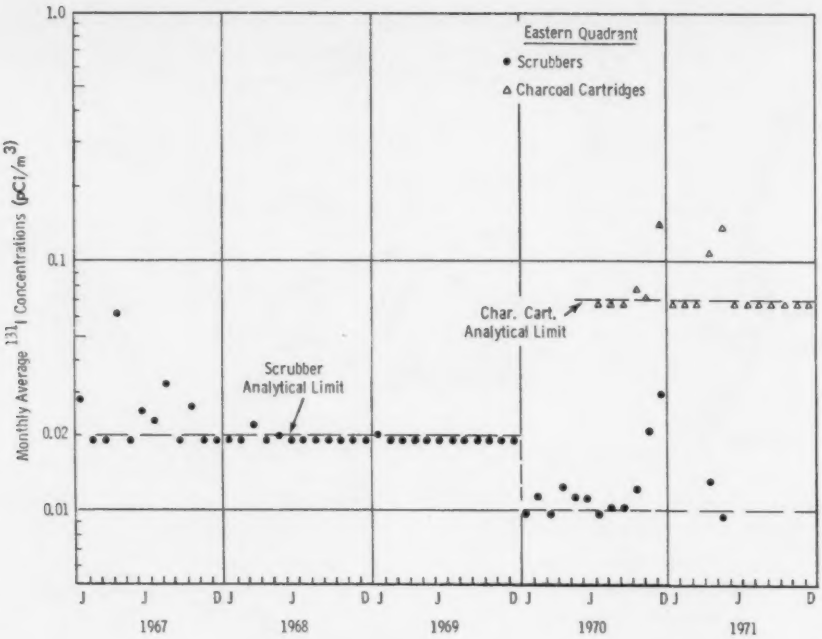

Figure 8. Monthly average iodine-131 concentrations in the air of Hanford environs

In mid-1970, caustic scrubbers for radioiodine sampling were replaced with activated charcoal cartridges. The activated charcoal has a much greater collection efficiency than the caustic solution for organic-bound radioiodines. Therefore, the apparently increased radioiodine concentrations noted after June 1970 only reflect this increased collection efficiency and not an actual change in airborne radionuclide concentrations. Airborne beta concentrations followed the annual cycle observed in previous years and showed about the same maximum and minimum values. Table 5 presents a more detailed review of the 1971 airborne radioactivity data and includes data from the sampling locations on or near the plant boundary. Activated charcoal sampling for iodine-131 was performed at the perimeter community locations but the samples were occasionally analyzed only when radioiodine was detected in other samples. Special analyses generally showed strontium-90 to account for less than 10 percent of the total beta radioactivity, which would raise the actual AEC radiation standard to 100 pCi/m^3. Average beta concentrations were less than 5 percent of the more restrictive AEC standards. Airborne alpha concentrations averaged less than 15 percent of the AEC standards for air and average iodine-131 concentrations were less than 0.1 percent of the AEC standards for air. Generally, the average airborne radioactivity concentrations at the Hanford boundary were the same as the more distant sampling locations, indicating that Hanford operations were not contributing significantly to offsite airborne radioactivity.

Radionuclides in milk

Irrigation with river water containing radionuclides can contribute radioactivity to local milk and locally grown farm produce, as can deposition of airborne materials from Hanford sources and from weapons test fallout. Chemical separations facilities would generally be the principal local source of airborne radionuclides other than fallout, although unusual radio-

Table 5. Radioactivity in air for 1971, Hanford Plant

Location	Alpha emitters (pCi/m³)					Beta emitters (pCi/m³)					Iodine-131 (pCi/m³)				
	Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Plant boundary sampling points:															
Yakima Barricade	25	0.012	[a]0.001	0.003	15	25	1.4	0.07	0.42	4.2	26	0.16	[a]0.006	0.004	0.004
Vernita	NS					26	2.1	.07	.47	4.7	NS				
Wahluke #2	NS					27	1.2	.06	.42	4.2	NS				
Berg Ranch	27	.015	[a].001	.002	10	27	1.3	.06	.44	4.4	27	.19	[a].015	.019	.019
Ringold	26	.015	[a].001	.003	15	26	1.3	.04	.39	3.9	27	.24	[a].0005	.023	.023
Byers Landing	25	.010	[a].001	.003	15	25	1.1	.06	.39	3.9	26	.15	[a].0003	.031	.031
Richland	26	.010	[a].001	.001	5	26	1.2	.06	.42	4.2	27	.34	[a].007	.037	.037
ECC	NS					25	1.0	.07	.40	4.0	NS				
Rattlesnake Spring	NS					25	1.4	.08	.46	4.6	NS				
Benton City	26	.014	[a].001	.001	5	26	1.4	.07	.42	4.2	27	.11	[a].004	.021	.021
Intermediate sampling points:															
Othello	24	.003	[a].001	.001	5	27	1.0	.05	.38	3.8	27	.19	[a].003	.032	.032
Wahluke Watermaster	NS					24	1.0	.03	.38	3.8	26	.20	[a].001	.012	.012
Connell	NS					27	1.3	.03	.44	4.4	27	.68	[a].004	.065	.065
New Moon	18	.002	[a].001	.001	5	26	.89	.03	.30	3.0	27	.18	[a].003	.023	.023
Eltopia	NS					27	1.1	.04	.39	3.9	NS				
Pasco	26	.016	[a].001	.003	15	26	1.2	.05	.42	4.2	26	.28	[a].002	.031	.031
Kennewick	NS					25	.90	.06	.38	3.8	NS				
Distant sampling points:															
Sunnyside	NS					26	1.0	.05	.34	3.4	NS				
Ellensburg	NS					23	1.1	.04	.31	3.1	NS				
Moses Lake	NS					25	1.3	.06	.40	4.0	NS				
Washtucna	NS					24	1.1	.04	.37	3.7	NS				
Walla Walla	21	.003	[a].001	.001	5	26	1.0	.05	.35	3.5	NS				
McNary Dam	18	.002	[a].001	.002	10	25	1.0	.07	.41	4.1	NS				
Analytical limit			0.001					0.02					0.07		
AEC standard			0.02					10					100		

[a] Less than analytical limit.
NS, no sample.

activity releases from ventilation stacks of reactor or laboratory facilities could be of interest.

The milk surveillance program maintained during 1971 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained zinc-65 and iodine-131, as well as fission products of fallout origin. Prior to February 1971 (no single-pass reactors operated after January 1971), milk from these farms contained detectable phosphorus-32. However, commercial milk distributed in the tri-cities usually did not contain detectable phosphorus-32 and zinc-65 because only a small fraction of this milk was produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

Figure 9 shows the monthly average concentration of phosphorus-32 and zinc-65 in milk from river-irrigated farms in the Ringold and Riverview area for 1967–1971. Phosphorus-32 analysis was discontinued after February 1971. Seasonal fluctuations in radionuclide concentrations, caused primarily by irrigation and feeding practices, followed expected trends. Average phosphorus-32 and zinc-65 concentrations in milk for 1971, as shown in table 6, were less than 0.1 percent of the AEC radiation standards. Even so, such concentrations would have been available only to a few local families.

Figure 10 shows the monthly average concentrations of iodine-131 in locally available milk. During 1971, iodine-131 concentrations in both farm milk and commercial milk generally were near or below the analytical limit

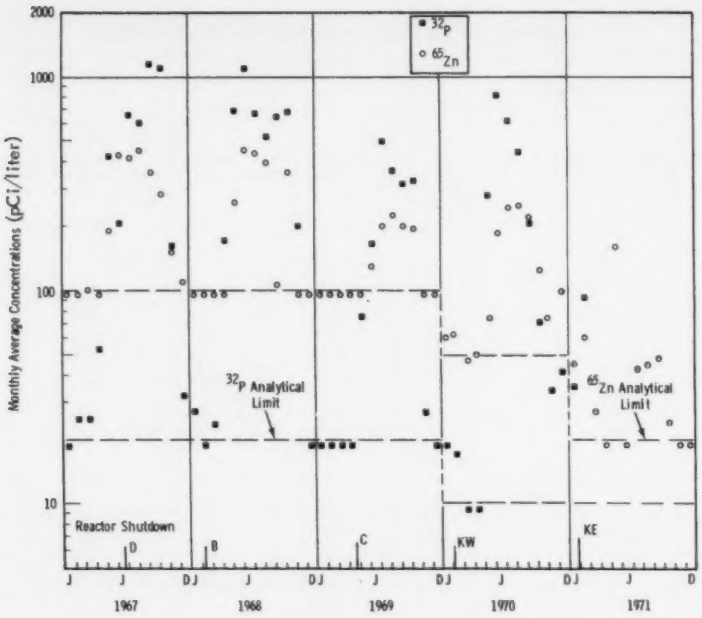

Figure 9. Monthly average phosphorus–32 and zinc–65 concentrations in milk from river-irrigated farms, Hanford

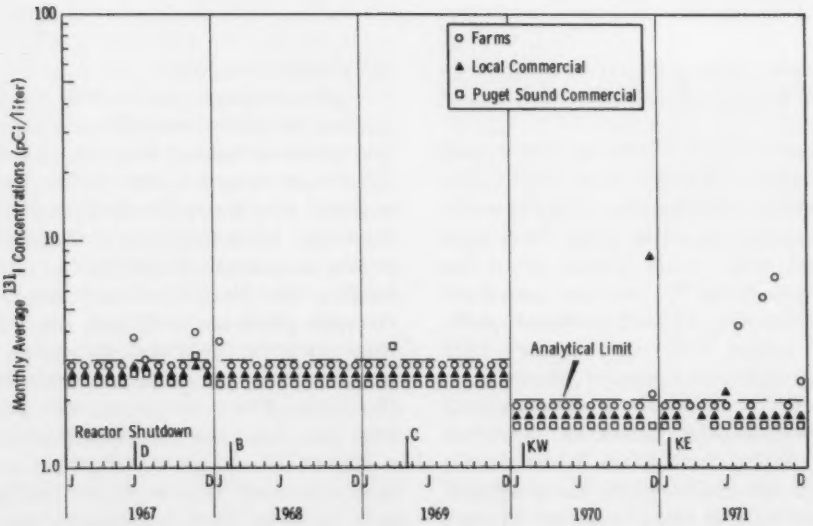

Figure 10. Monthly average iodine–131 concentrations in locally available milk, Hanford

Table 6. Radionuclide concentrations in locally purchased milk, 1971

Sampling location	Number of samples	Radionuclide concentration (pCi/liter)									
		Phosphorus-32		Zinc-65		Strontium-90		Iodine-131		Cesium-137	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Riverview	1	100	[a] 15	220	54	5	2	2	[a] 1	28	[a] 18
Benton City and West Richland composite	52	([a])	([a])	210	22	3	2	25	[a] 1	92	[a] 16
Columbia River basin composite	52	([a])	([a])	200	25	2	[a] 1	3	[a] 1	81	[a] 18
Commercial	2	([a])	([a])	170	28	6	4	3	[a] 1	50	26
AEC standard		20 000		100 000		300		300		20 000	
Analytical limit (water)		20		20		2		2		20	

[a] Less than analytical limit.
Note: Minimum detected activities were all below the analytical limit and therefore not included in this table.

(2 pCi/liter). The maximum iodine-131 concentration for this period, (25 pCi/liter) was measured in a single sample of farm milk collected on December 2. The average iodine-131 concentrations locally available in farm milk for 1971 (table 6) were less than 0.5 percent of the AEC standards for water. Increases of iodine-131 concentrations in milk, attributed to fallout from atmospheric nuclear weapons testing, were observed the latter part of 1971.

The concentrations of other fallout nuclides, strontium-90 and cesium-137, in the local environs usually are below the national average because of the low rainfall. Measurements of fallout, like measurements of natural background radiation, help to put the radionuclide concentrations resulting from Hanford operations, in proper perspective.

Concentration of strontium-90 in locally produced farm and commercial milk (figure 11) are similar to those in commercial milk produced in other areas of low rainfall remote from the Hanford plant. Concentrations of cesium-137 (figure 12) averaged near the analytical limit of 20 pCi/liter. Regional fallout from nuclear weapons testing is the source of strontium-90 and cesium-137 in milk.

Concentrations of strontium-90 and cesium-137 in locally available milk averaged less than 1.4 percent and 0.3 percent of the respective AEC Radiation Protection Standards (5) for water.

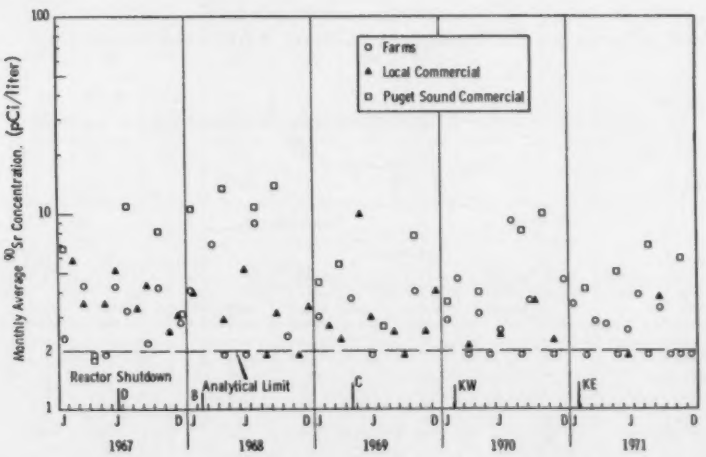

Figure 11. Monthly average strontium-90 concentrations in locally available milk, Hanford

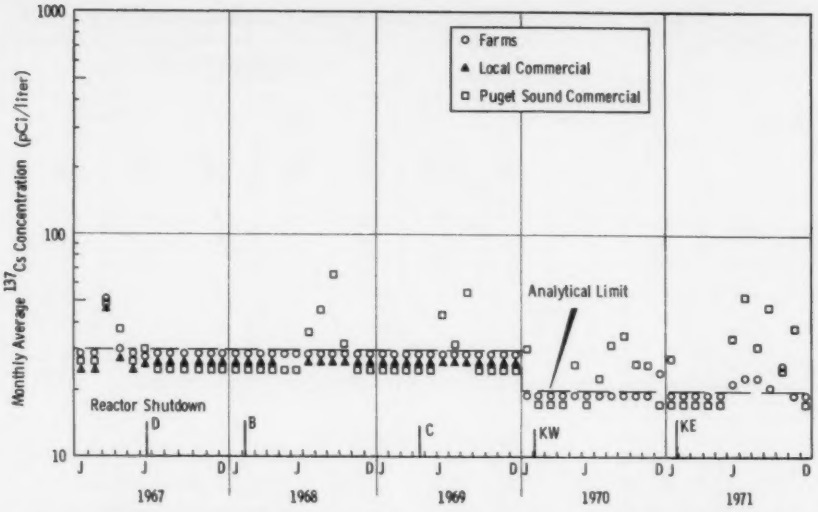

Figure 12. Monthly average cesium–137 concentrations in locally available milk, Hanford

Radionuclides in foods

A program of sampling the meat and produce of local farms and stores was conducted throughout 1971. Sampling schedules were geared to local foodstuff production schedules. Meat was obtained from Riverview farms and local stores. Leafy vegetables were obtained from Riverview farms in July, August, and September, and from local stores in May through October. Table 7 shows that, on the average, concentrations of reactor-produced zinc-65 were higher in local farm foodstuffs than in locally available commercial products.

Table 7. Radionuclide concentrations in locally purchased food, 1971

Foodstuffs	Number of samples	Radionuclide concentration (pCi/g wet weight)							
		Phosphorus–32		Zinc–65		Strontium–90		Zirconium–niobium–95	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Commercial meat	12	[a]	[a]	[a]	[a]	0.013	0.003	[a]	[a]
Poultry	2	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Eggs	10	[a]	[a]	0.93	0.23	.012	.007	[a]	[a]
Local produce	3	[a]	[a]	[a] .023	[a] .014	[a]	[a]	0.13	0.021
Commercial produce	5	[a]	[a]	[a]	[a]	.039	.008	.046	.046
Analytical limit			1.0		0.030		0.002		0.010

Foodstuffs	Number of samples	Ruthenium–106		Iodine–131		Cesium–137		Cerium-praseodymium–144	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Commercial meat	12	[a]	[a]	[a]	[a]	0.194	0.053	[a]	[a]
Poultry	2	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Eggs	10	[a]	[a]	[a]	[a]	[a].015	[a]	[a]	[a]
Local produce	3	[a]	[a]	[a]	[a]	.046	[a].016	[a]	[a]
Commercial produce	5	3.3	0.82	[a]	[a]	.18	.047	5.3	1.5
Analytical limit			0.370		0.025		0.017		0.350

[a] Less than analytical limit.
Note: Minimum detected activities were all below the analytical limit and therefore not included in this table.

Conversely, the concentrations of fallout radionuclides (strontium-90, cesium-137, cerium praseodymium-144, zirconium-niobium-95, and ruthenium-106) were higher in the commercial foodstuffs. Although concentration or daily intake guides for radionuclides other than strontium-90 and cesium-137 are not specifically available for foods, it is common practice and provides an appropriate perspective to compare radionuclide concentrations in foods with AEC standards for water, keeping in mind that such a comparison implies continued daily intake of foodstuffs. Radionuclides in milk and food are shown in tables 6 and 7.

Radionuclides in fish, shellfish, and gamebirds

Fish in the Columbia River downstream from the single-pass Hanford reactors acquired radionuclides originating with reactor effluent. Historically, whitefish were the fish species caught and consumed locally that usually contained the greatest concentrations of radioactive material. However, panfish species were of greater significance as a source of human exposure due to the difference in quantities consumed (*6*). Phosphorus-32 concentrations in whitefish dropped to less than the analytical limit of 1 pCi/g wet weight within a month after shutdown of the KE reactor. Radionuclide concentrations of other nuclides and other fish species would have been of even less significance as a source of human exposure. Zinc-65 and phosphorus-32 are the only radionuclides from Hanford reactor effluents that have been found in sufficient abundance in food organisms beyond the mouth of the Columbia River to be of significance to human radiation exposure. Oysters have been found to contain higher concentrations of zinc-65 than other common seafoods (*7*). A normal seasonal minimum for phosphorus-32 occurs in the late summer, due to seasonal changes of ocean currents. For 1971, the concentrations of phosphorus-32 were so low that negligible quantities of phosphorus-32 were found in Willapa Bay oysters. Concentrations of zinc-65 decreased at a rate closely corresponding to its radioactive decay.

Waterfowl and other gamebirds utilizing the river downstream from the reactors may acquire radionuclides as a result of ingestion of insects, algae, vegetation, and water containing these radionuclides. Some water fowl remain in this general area throughout the year. The concentrations of radionuclides in game birds are dependent upon the bird species, the geographical locations of the birds, and their current feeding habits. Data from a dietary survey of Hanford employees and from a special survey of local hunters (*8*) indicate that about 30 percent of the game bird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. The same studies showed that about 30 percent of all gamebirds taken locally were ducks and geese, and that the average Richland resident consumed 1.4 kg/yr of gamebirds.

Table 8. Average radionuclide concentrations in muscle of gamebirds, 1971

Species	Radionuclide concentration (pCi/g)															
	Sodium-24				Phosphorus-32				Zinc-65				Cesium-137			
	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average
Geese (river)[a]	10	[b]	[b]	[b]	10	1.2	[b] 0	[b] 0	10	1.4	[b]	0.57	10	0.55	[b] 0	0.097
Duck (river)[a]	79	5.2	[b]	0.97	31	170.0	[b] 0	19	79	15.0	[b] 0	.63	79	.28	[b] C	.046
Pheasant [c]	NA	NA	NA	NA	NA	NA	NA	NA	16	.35	[b] 0	[b]	16	.13	[b] .002	.08
Analytical limit	0.6				1.0				0.2				0.1			

[a] Collected in January 1971 on the Columbia River within the Hanford boundary.
[b] Less than analytical detection limit.
[c] Collected in November and December 1971 within 5 km (3 miles) of the Columbia River and within the Hanford boundary.
NA, no analysis.

The average concentrations of several radionuclides in the muscle (the edible portion) of 89 waterfowl samples collected on the river within the Hanford boundaries for the environmental monitoring program during hunting seasons in 1971 are shown in table 8. Average radionuclide concentrations in muscle for 16 pheasants collected at the Hanford site also appear in table 8.

Radionuclide concentrations in gamebirds in 1971 generally were below the levels recorded in 1970. Geese generally were lower in radionuclide concentrations than ducks taken from the same areas. Only zinc-65 was consistently above detectable limits after the KE reactor shut down.

There are no appropriate AEC standards with which to compare the gamebird radionuclide concentrations because of the limited period of the year during which hunting is permitted and consumption usually occurs.

Dose estimates using the dietary studies (*6,8,9*), combined with concentration data from the various species, indicated that the dose received by the average Richland resident (adult) from gamebird consumption was less than 1 mrem for 1971.

Soil and vegetation

Thirteen stations for routine soil and vegetation sampling were established around the perimeter of the Hanford reservation in 1971. Samples of the top 5 cm (2 inches) of soil and native vegetation (perennial) were taken at each of these stations at the end of September, and analyzed for plutonium, strontium-90, and gamma emitters. The averaged results from all stations are given in table 9. Individuals results, tabulated in BNWL-1683 (ADD) showed no particular geographical pattern, and the concentrations measured are believed to be the result of regional fallout.

Gamma emitters in soil samples were measured with a germanium crystal detector; in vegetation samples, with a sodium iodide crystal. As a result, slight differences in the gamma spectra were reported. Since the bulk of the vegetation was perennial, no conclusions should be drawn as to uptake of radionuclides from the soil. The plutonium concentrations are typical of general regional levels for the arid western states. No valid standards exist for nuclides in soil and desert vegetation.

External radiation

Clusters of three ionization chambers[3] are maintained at selected locations within the plant boundary and at Richland and have been used to measure the gamma radiation exposure at 1 meter above ground level for many years (table 10), although it was recognized that the results were conservatively high. Thermo-

[3] Victoreen stray radiation chambers, 100-ml.

Table 9. Radionuclides in soil and vegetation, 1971

Radionuclides	Concentration (pCi/g wet weight)					
	Soil			Vegetation		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Cobalt-58	0.08	(a)	0.017	(a)	(a)	(a)
Cobalt-60	.12	(a)	.032	(a)	(a)	(a)
Zinc-65	.29	(a)	.068	(a)	(a)	(a)
Strontium-90	.99	(a)	.18	0.78	0.07	0.21
Zirconium-niobium-95	(a)	(a)	(a)	2.7	.68	1.6
Ruthenium-106	2.3	(a)	.45	2.71	(a)	.95
Cesium-137	1.3	.33	.66	.82	.15	.43
Cerium-praseodymium-144	1.2	(a)	.44	10.6	1.1	4.7
Plutonium-238	.0067	(a)	.0029	.0038	(a)	(a)
Plutonium-239, 240	.018	(a)	.011	.011	(a)	.004

[a] Less than analytical limit.

Table 10. Radiation exposure rates at Richland from ionization chambers, 1967–1971

Location	Exposure rate (mR/yr)				
	1967	1968	1969	1970	1971
Hanford test location	0.35	0.36	0.37	0.39	0.40
Richland	.26	.28	.30	.34	.34

luminescent dosimeters (TLD-200)[4] were introduced into the routine surveillance program in 1970, and were available for the full year of 1971. Although table 11 is included as an indication of long-range trends, the more significant data for 1971 is a comparison of annual average exposure data from all monitored locations (the same as air sampling locations, figure 6). This shows the same value of 58 mR/yr for both eastern quadrant locations, adjacent to the Hanford plant, and the more remote perimeter communities locations.

Estimates of the external radiation dose received from recreational use of the Columbia River in the vicinity of the Hanford project have been based on routine measurements at the shoreline at Richland and Sacajawea Park (where the Snake River enters the Columbia) and below the surface of the river at Richland. The average exposure rates at the two shoreline locations (figure 13) were taken from measurements with a large (40 liter) ionization chamber prior to July 1971, and with a low-level dose rate meter[5] subsequently. Measurements were taken at 1 meter back from the water's edge and centered 1 meter above the ground, which approximates the dose rates to the gonads of a person on the riverbank. The exposure rates measured at the shoreline include components from radioactivity accumulated in sediment deposits and algae growths at the river's edge as well as from any radioactive material in the water. The same data, tabulated

[4] Harshaw Chemical Company, $CaF_2(Dy)$.
[5] Nuclear Enterprises Model.

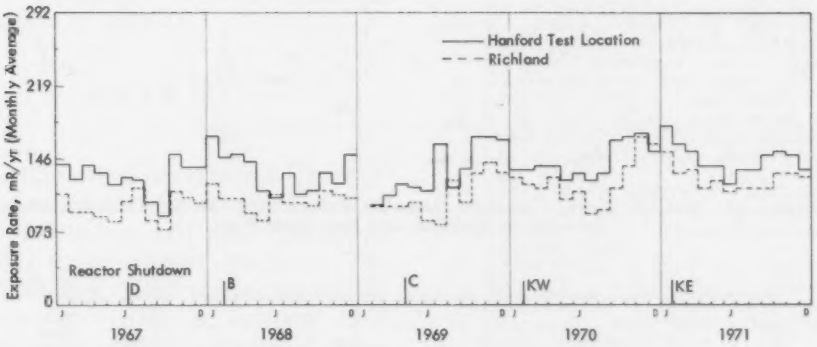

Figure 13. Monthly average gamma rates at Hanford test location and at Richland

Table 11. Radiation exposure rates at the Columbia River shoreline, 1967–1971

Location	Exposure rate															
	1968				1969				1970				1971			
	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
Richland	3.6	.12	1.1	400	1.5	0.30	0.71	260	1.1	0.14	0.44	160	0.77	0.12	0.30	110
Sacajawea Park	1.5	.24	.67	240	1.5	.30	.60	220	1.3	.24	.52	190	.60	.12	.30	110

in table 11, show the effect of shutdown of the single-pass reactors. Averages for 1971 are not significantly different from local background measurements with the same instrument.

The immersion dose received by tri-city swimmers is based on April through October exposure rates at Richland measured with thermoluminescent dosimeters positioned about 1 meter below the surface of the Columbia River. Measured immersion exposure rates primarily were due to the gamma emitters in the river. In the vicinity of Richland, the average measured immersion exposure rate from April through October 1971 was 0.15 mR/day, attributed to natural radioactivity.

Table 12. Comparable dose estimates[a] for average Richland resident, 1967–1971

Organ	Percent of AEC standard					Dose standard (mrem/yr)
	1967	1968	1969	1970	1971	
Bone	3	3	3	2	<1	500
Whole body	3	2	2	1	<1	170
GI tract	6	5	4	2	<1	500
Thyroid (infant)	8	8	5	2	<1	500

[a] Not including contributions from fallout of natural background radiation.

Population dose implications

Since 1958, a major part of the environmental surveillance effort at Hanford has been addressed to the estimation of radiation doses

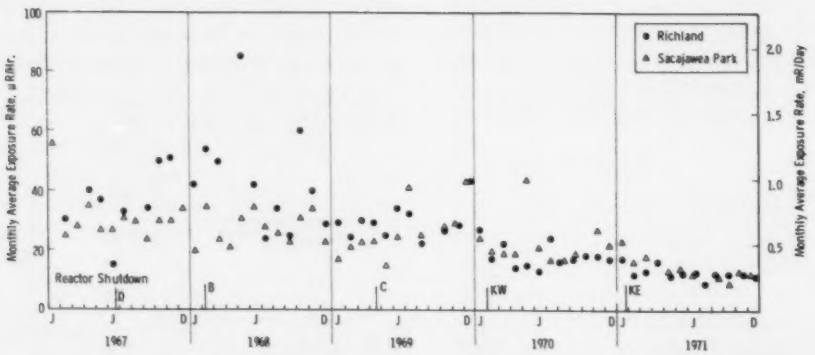

Figure 14. Monthly average external gamma exposure rates at the Columbia river shoreline at Richland and Sacajawea Park

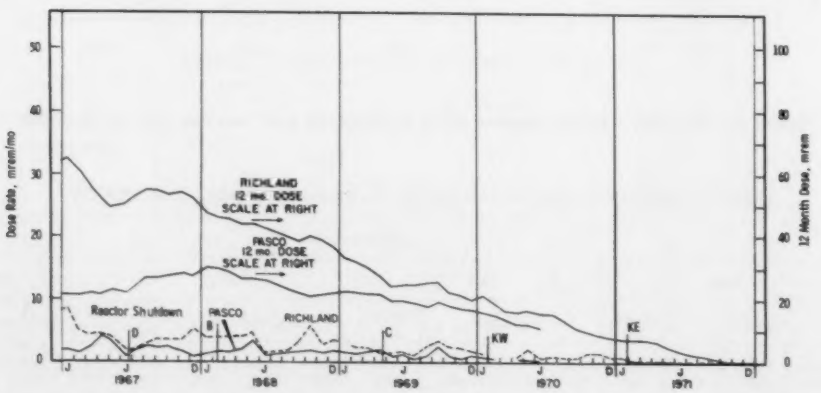

Figure 15. Doses to the G.I. tract from Richland and Pasco drinking water (1.86 liter/day intake rate)

Table 13. Radiation dose commitments from ingestion of fallout nuclides and comparison with radiation doses from plant sources, 1971

Organ	Dose (mrem)				
	Tritium	Strontium–90	Cesium–137	Total from fallout	Total dose from plant sources
Maximum individual:					
Bone		[b] 30	1	31	3
Whole body	<1	[b] 3	[c] <1	3	3
GI tract		<1	<1	<1	3
Average Richland resident:					
Bone		[b] 15	<1	15	<1
Whole body	<1	[b] 1	[c] <1	2	<1
GI tract		<1	<1	<1	<1

[a] Not including natural radioactivity.
[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods. Only a few percent of the total dose commitment from strontium–90 intake is received during the first year for each of these organs.
[c] For the whole body dose commitment from ingestion of cesium–137 by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used.

to the surrounding population, with methods detailed in references *1* and *10*. The trend of these estimates with the step-wise shutdown of the single-pass production reactors is indicated by table 12 and figures 14 and 15. For comparison, estimates of radiation dose to the local population from nuclear weapons testing fallout are shown in table 13.

Summary

The 1971 Hanford Environmental Surveillance Program showed continued compliance of the Hanford contractors and their operations with applicable environmental standards. The shutdown of the last of the single-pass cooled production reactors (KE) in January 1971 eliminated the major remaining source of radioactivity released offsite and of population exposure from Hanford operations. No unusual releases occurred causing AEC standards, as given in AEC Manual Chapter 0524, Appendix, Table II, to be exceeded. All measurements of radioactivity outside the plant boundaries were less than 15 percent of the applicable AEC standards. Radiation dose estimates for population groups in the plant environs for 1971 were all less than 1 percent of applicable standards for plant operations. Offsite measurements of other air and water quality parameters also were well within applicable criteria and showed no significant evidence of plant operations.

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1970	April 1974

Reported Nuclear Detonations, May 1974

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Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States on May 15, 1974. The signals originated at 11:03 p.m., EDT, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

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CALCULATIONS OF DOSE, POPULATION DOSE AND HEALTH EFFECTS DUE TO BOILING WATER NUCLEAR POWER REACTOR RADIONUCLIDE EMISSIONS IN THE UNITED STATES DURING 1971. *J. A. Martin, Jr.* and *C. B. Nelson. Radiation Data and Reports, Vol. 15,* June 1974, pp. 309–319.

Atmospheric emissions of radionuclides during 1971 reported by operators of 10 boiling water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A recently developed computer program (AIREM) was used to perform the calculations. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 80 kilometers. In 1971, 3.2 million curies of radioactivity were released to the atmosphere from 10 reactors. The resulting whole body population dose was calculated to be 900 person-rem. The health effects associated with this population dose were calculated to be small fractions of those induced by natural background radiation.

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